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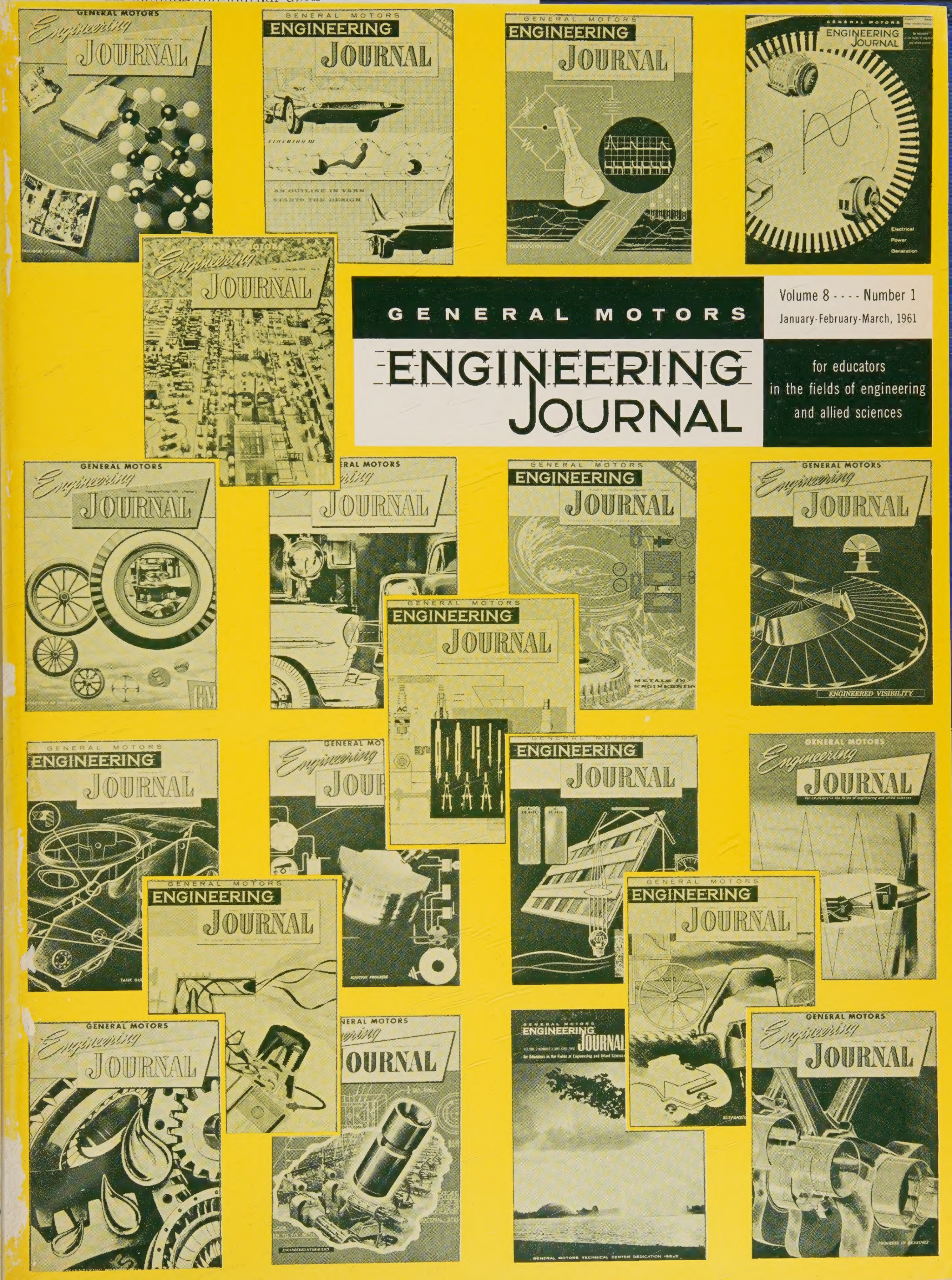
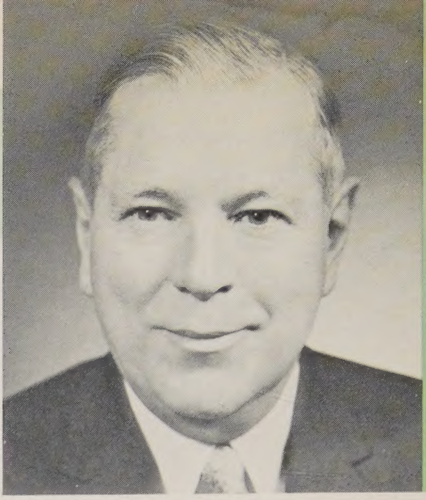
GENERAL MOTORS ENGINEERING JOURNAL

for educators in the fields of engineering and allied sciences



Opportunity Knocks More Than Once



If you are a young engineer—or a student soon to begin your engineering career—I suggest that you doubt the truth of a widely known saying: Opportunity knocks only once.

Too often, we think of opportunity as a windfall type of thing—the one chance to make a big kill. Actually, it will be a succession of many knocks on your door as your career unfolds. Opportunity is inherent in each job assignment you will be given. In every case you will have the chance to prove your mettle, to show what you can do, and to learn still more.

Opportunity is the chance to prepare yourself for the next rung on the ladder—and not necessarily the chance to go from the bottom rung to the top all in one jump!

What are some of the ways to prepare yourself to climb the rungs ahead of you?

First of all, you should recognize that you must do the job yourself. Others may be able to help you, but the burden is substantially yours. Second, you should avoid procrastination. This can be the greatest obstacle in the path of your progress. It is easy to delay for a little while—until that little while has mounted up to years and a point of no return has been reached.

Based upon my experience with engineers in General Motors, these are some additional suggestions that you may find helpful:

(a) *Be alert and curious.* Learn thoroughly each job assignment given you and at the same time learn all you can about others for which you may become eligible. Take advantage of training programs.

(b) *Adopt an educational and reading program.* Recognize that education does not cease with the granting of a college diploma. After college, you are responsible for establishing and reaching your own educational objectives. You may find it to your advantage to return to college for special courses taken in your spare time. You also may find that extensive reading, in both special and general fields, will help in reaching your educational goals.

(c) *Take a positive attitude in your adjustment from campus to industry.* The habits and concepts that you develop during your first years in industry are likely to stick with you. Sink your roots in the community. Develop a sense of belonging. As a good citizen, give of yourself to the community, and take advantage of what it has to offer to you.

(d) *Develop a broader perspective.* Keep your eyes open to what is going on in the world around you. Business today is affected by many social, economic and political phenomena, both domestic and international, with which earlier generations did not have to contend. The more understanding of these which you can acquire, the better equipped you will be for more responsible positions later in your career.

Will you be able to foresee your opportunities? Sometimes you will.

More often, they will develop in wholly unexpected ways. Life has no set patterns that will cast opportunities at your feet at just the right time and in just the form you desire.

However, carrying out your own self-development program will help you prepare yourself so that when opportunities do come your way, you will be able to recognize them and to handle them intelligently, promptly, and properly.

L. C. Goad,
Executive Vice President

THE COVER

With this issue the GENERAL MOTORS ENGINEERING JOURNAL marks a milestone in its history: the publication of more than one million copies. In the cover design, artist Ernest W. Scanes recalls a selection of JOURNAL covers from the previous seven volumes.

The millionth copy of this publication signifies many things. But especially, it is a dual recognition of the interest shown by the reader audience and the work of GM personnel who contribute papers.

After the first experimental issue was published in 1953, one educator commented, "I was pleased to discover that the articles were chosen to interest every field of engineering, plus, physics and chemistry." On the way to a 1,000,000-copy total, the JOURNAL has endeavored to provide this kind of subject variety while adhering to the basic purpose of supplying information useful to educators in connection with classroom work. Topics have ranged from the conventional, such as a beam strength problem, to the unusual, such as a *Magnus Effect* flowmeter.

Sent on a request basis, the JOURNAL now reaches faculty members in more than 800 educational institutions in the United States and other countries, as well as technical personnel in General Motors operations everywhere.

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GENERAL MOTORS ENGINEERING JOURNAL

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The GENERAL MOTORS ENGINEERING JOURNAL is published quarterly by the Educational Relations Section of the Public Relations Staff, General Motors Corporation. It is intended primarily as a medium for presenting to educators in the fields of engineering and allied sciences the results of General Motors research and engineering developments in both the product and production fields.

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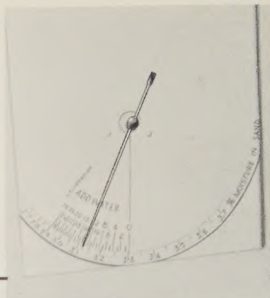
A Nuclear Method for Measuring the Moisture Content of Foundry Sand



By HARVEY A. BURLEY
and ARTHUR D. BLOCK
General Motors
Research Laboratories
and MILTON J. DIAMOND
Central Foundry Division

The problem of sand moisture control has plagued foundrymen for years. Recent advancements in foundry technology have emphasized the need for a faster and a more reliable moisture measuring device that can be integrated into complex sand handling systems. To solve this problem Central Foundry Division and GM Research Laboratories jointly developed a moisture gage which can measure the average moisture content of a 3,200-lb batch of sand to an accuracy of ± 0.05 per cent at the three per cent level in less than one minute. The gage uses a two-curie plutonium-beryllium neutron source which emits fast neutrons that are slowed by the hydrogen nuclei of the water contained in the sand. By employing detectors sensitive only to these slow neutrons, an output measurement is obtained which is directly proportional to the moisture content of the sand. Electronic equipment amplifies and counts the electrical pulses from the detectors and the moisture content of the sand is indicated on a large dial. The system, now in operation at the Danville, Illinois, plant of Central Foundry, has no adverse effect on the sand.

A peacetime application of plutonium-239 solves an old foundry problem

PROGRESS in the foundry industry has been due more to a steady, workmanlike elimination of variables and unknowns than to a few dazzling technological breakthroughs. The gradual refinement of melting, pouring, heat treating, and testing techniques has not only resulted in better castings, but it has greatly increased the number and the variety of jobs which can be handled successfully by the industry.

Foundry management has learned the value of long range planning of foundry improvements and is convinced that today's research helps enlarge future markets.

An example of such advance planning is a program recently undertaken by Central Foundry Division. It recognized the increased need for a better method of controlling the moisture content of foundry sand.

The system in use involved taking samples of the sand once each hour and checking the moisture content by comparing the sand weight before and after a standard oven-drying procedure. To help maintain the correct moisture content, the muller operator continuously hand-sampled the sand and, judging by its feel after it was compressed, adjusted the flow of water into the muller. Although this system worked surprisingly well, the Central Foundry management felt the system should be improved since:

(a) The time period that occurred between taking the lab samples and informing the operator of the results was at least 30 minutes. Meanwhile, on a typical system, approximately 100 tons of sand had been processed before accurate results could be obtained

(b) The temperature extremes affected the operator's feel of the sand

(c) The judgment needed for the feel system took an operator years to acquire and when less experienced operators took over, they were often unable to keep within the standards

(d) The newer, more complicated castings (such as cast crankshafts) required more rigid control of sand moisture. If the moisture content dropped too low, molds broke; if it went too high, scabs and blow holes appeared in the metal

(e) The size of the hourly sample (100 grams) was out of proportion to the approximately 200 tons per hour going through the sand system.

With these factors in mind, Central Foundry contacted the Physics Department of the GM Research Laboratories to determine whether a device could be developed that would test a larger proportion of the sand and reliably indicate its moisture content to an accuracy of about $\pm$ 0.05 per cent moisture content at the three per cent level.

Several moisture determination methods were investigated. One of the most obvious methods—electrical conductivity—had to be discarded because one constituent of the molding sand was powdered sea coal. The presence of conductors such as carbon in varying amounts ruled out the conductivity system. Two systems utilizing radioactive materials were investigated, one using fast neutrons and the other gamma rays. Field tests indicated the fast neutron system had the greatest possibility of success.

How Neutron Principle Was Applied to the Problem

To understand why this system was chosen, it is first necessary to investigate part of the operational theory involved.

Neutrons are electrically neutral, elementary nuclear particles having a mass approximately the same as that of a hydrogen atom. They are usually divided into several sub-classifications according to their energies. Thermal or slow neutrons have an energy of approximately 0.025 electron volts and an average velocity of about 2.2×10^5 cm per sec

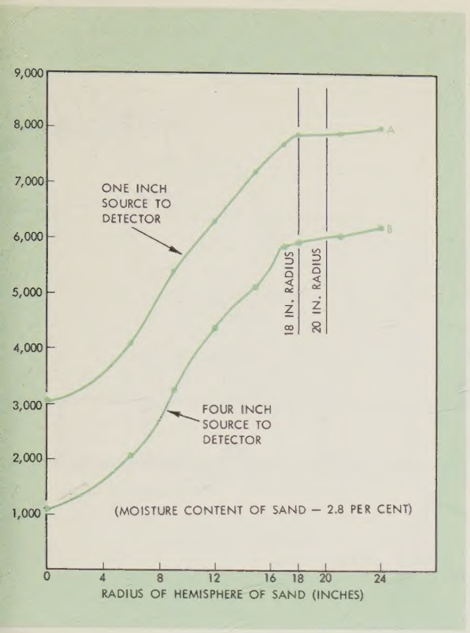


Fig. 1—This chart shows the experimental relationship between the quantity of sand and the neutron count rate. Two source-detector orientations were used for the experiments; a one inch spacing (curve *A*) and a four inch spacing (curve *B*). In both cases the addition of more than a 20-in. radius of sand produced little increase in the detector count rate.

(1.4 miles per second). The term fast neutrons is applied to the group having an energy of 0.1 million electron volts or greater. A one-mev fast neutron has a velocity of about 1.4×10^9 cm per sec (8,900 miles per second). If hydrogen nuclei are present in a field of fast neutrons, there is a probability that collision will result and the fast neutrons will lose some of their energy. It takes an average of 18 such collisions to reduce a two-mev fast neutron to its thermal energy[1]. Heavier elements require a much greater number of collisions to thermalize the fast neutrons, thus the system is sensitive primarily to hydrogen.

To apply this phenomenon to the Central Foundry problem required a source of fast neutrons and a detector sensitive to thermal neutrons only. The engineers knew that if a source and a detector were placed in the foundry sand, the number of slow neutrons present would be proportional to the number of hydrogen nuclei present. Furthermore, since the only hydrogen present in significant amounts in foundry sand is in the form of moisture, the output from the thermal neutron detector could be related directly to the moisture content of the sand. This principle had been tried before for other purposes, but the accuracy and speed Central Foundry required in the low moisture regions had never been achieved[2,3].

Laboratory Experiments Tested Operational Theory

Since an average of 18 collisions is required to reduce the energy of a two-mev fast neutron to that of its thermal state (0.025 ev), a certain minimum volume of sand is required to produce the maximum possible thermal neutron field. This critical volume was determined experimentally by placing a thermal neutron detector and a fast neutron source under a hemisphere of sand. Sand was gradually added, maintaining the hemisphere shape, until the addition of further sand no longer increased the output from the neutron detector (Fig. 1). The experiment was performed about four feet above the floor on a support of sheet steel to minimize outside interference.

This experiment indicated that a fast neutron source and a thermal neutron detector inserted in a large quantity of sand would affect a sphere only about 36 to 40 in. in diameter and the use of a smaller quantity of sand would result in uneconomical use of neutrons. (The detector output would be reduced if less than this optimum quantity of sand was used.) It further indicated that if the correct amount of sand were used, the possibility of outside interference from hydrogenous materials would be greatly reduced.

It was concluded that the greatest chance for success lay in mounting the source and the detector in a large bin or hopper. Tests in a storage bin resulted in poor correlation between neutron count rate and actual moisture (as determined by a number of small oven dried samples).

The gage, however, functioned correctly when the neutron probe was lowered through an access tube into the weigh lorry. The lorry was used to weigh the 3,200-lb charge that was later dropped into the muller. By this method the sand geometry was fixed and the quantity was always the same, making it possible to obtain an excellent calibration curve of count rate versus per cent of moisture (Fig. 2).

From the field tests it was concluded that a fixed installation could be built which would meet the accuracy and speed requirements. Measurements made with a neutron survey meter during these tests indicated that, with the addition of a small amount of shielding, the gage was completely safe to use and the radiation from the source had no effect on the sand.

Radioactive Disintegration Provided Design Problems

The next stage was to consider the design problems for a permanent installation. The disintegration of radioactive material occurs at randomly spaced intervals. As a result, an infinite number of counts must be collected to determine the true count rate. If less than an infinite number is collected, the probable deviation of the indicated count rate from the true count rate can be defined by an elementary statistical formula

$$\text{Per Cent of Probable Error} = \frac{67.45}{\sqrt{N}}$$

where N = the total number of counts.

In nuclear applications the concept of reliable error is more useful. It is

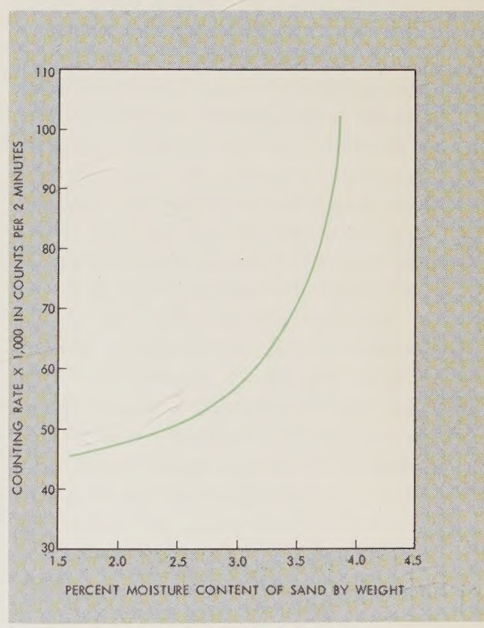
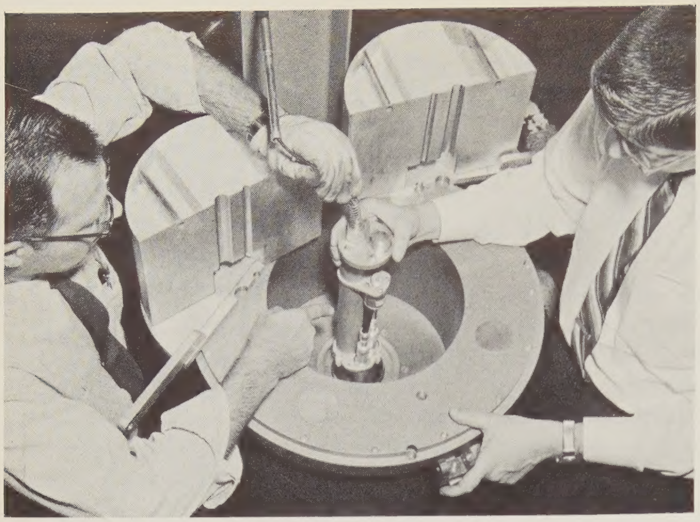


Fig. 2—This calibration curve shows the relationship between sand moisture and detector output as determined experimentally by using 3,200-lb batches of sand and a neutron probe containing a polonium-beryllium source. The procedure was to fill the weigh lorry, take two 2-minute counts, dump the sand into the muller, mix for about one minute, and then take two samples from the muller for oven drying. Before the points were plotted, the count rates were normalized with respect to the quantity of sand in the lorry and with respect to any changes occurring in calibration due to thermal drift in the system plus the normal decay of the source.



defined as the deviation which will not be exceeded 90 per cent of the time or

$$\text{Per Cent of Reliable Error} = \frac{165}{\sqrt{N}}.$$

An important point is that the accuracy of a measurement depends only on the number of counts collected. The more counts collected, the more accurate the reading. Collection time is not a factor. It is important to realize that a series of count runs taken under identical circumstances would each yield slightly different results. A tabulation of the results of such a series of runs should show that half the runs differ from the *true* count rate by a percentage that is within the probable error as defined by the formula. Ninety per cent of the runs should be within the reliable error of the true count rate.

This unavoidable error, due to the random nature of radioactive disintegration is generally referred to as *statistical error*. In designing a nuclear system of any kind this statistical error must be added to the more common errors introduced by meters, circuit non-linearities and instabilities, timers, and relays. The common errors are reduced and sometimes eliminated by good design practice but the statistical error is reduced only by increasing N, the number of counts. An examination of the calibration curve (Fig. 2) reveals that if the moisture must be read to ± 0.05 per cent at the 3-per cent level, it is necessary to have an overall system accuracy of one per cent or better.

It is evident that the associated counting and indicating equipment should be chosen so as to introduce the least error. Preset time scalers and rate meters were

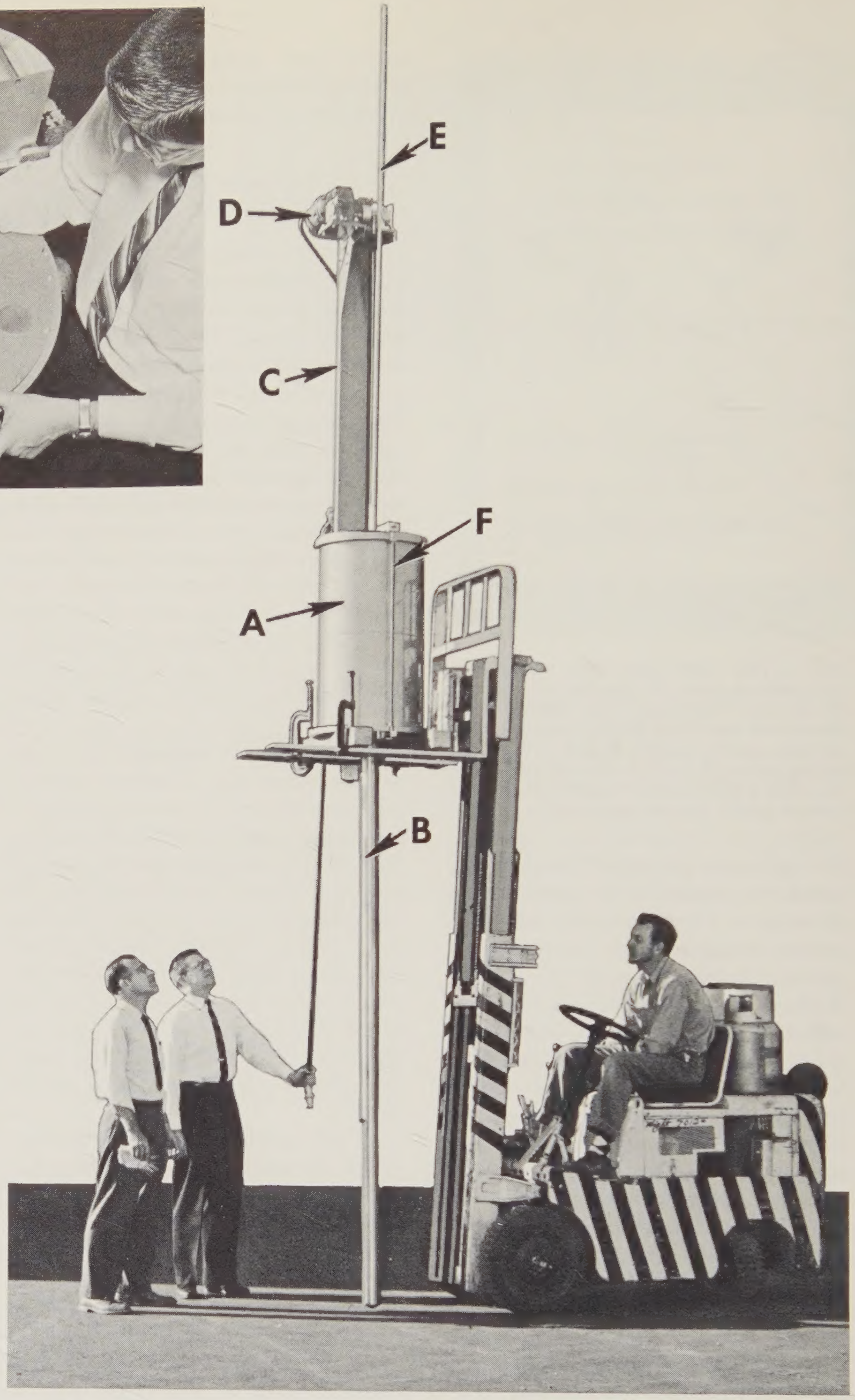


Fig. 3—The mechanical assembly of the moisture gage is shown here before shipment to the Central Foundry plant. The large cylinder A is a wax-filled shield and calibration drum. A stainless steel access tube B extends below the cylinder. In the plant operation, this tube extends into the sand and the source and detector assembly is lowered into the tube to obtain measurements. A steel channel C supports a one-third horsepower, 440-volt, three-phase motor and clutch assembly D. The motor drives the detector and source assembly down the access tube for measurements and back up the tube for calibration or storage in the shield drum. When the desired position has been reached, a clutch disengages the motor and a brake stops the assembly with a minimum of overshoot. A long pipe E houses the coaxial cable that carries the signal from the detectors to the amplifier. The small steel rod F in front of the cylinder is part of the interlock arrangement. Two locks are provided, one at the top of the cylinder and the other at the bottom. The bottom lock is removed each morning by the operator enabling the source to be moved down the access tube for normal operation. The top lock is removed only by qualified personnel for inspecting the source or for replacing neutron detector tubes.

The inset shows a top view of the shield and calibration drum with the upper lock, cover plates, and shield blocks removed. The plutonium-beryllium source tube is in the center of the cylinder with the two thermal neutron tubes adjacent to it.

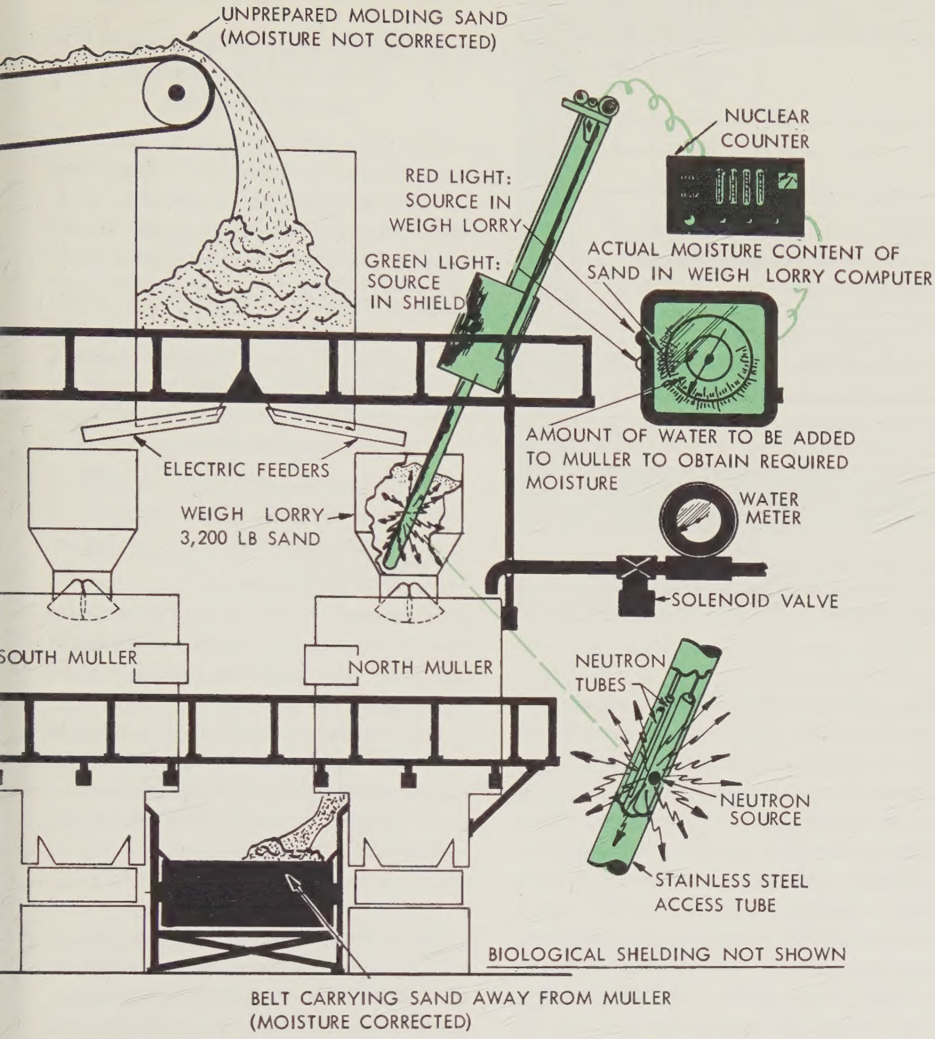


Fig. 4—This schematic drawing illustrates the general arrangement of the weigh lorries, mullers, probe device, and instrumentation used with the moisture gage. A two-curie plutonium-beryllium neutron source in the probe emits fast neutrons which are slowed by the hydrogen nuclei of water in the sand. This radiation output is proportional to the amount of moisture in the sand. The moisture content is measured by suitable detecting and amplifying equipment. Water can be added as needed to meet a specification. This method is faster and more accurate than previous methods used for measuring the moisture content.

examined for this application. The combination which offered the greatest advantage in both accuracy and readability was a preset count-type arrangement controlling a timer motor (constant speed), which drove a large moisture indicating pointer. This type of scaler can be set to accumulate a predetermined number of counts, after which it sends out a control signal. With very moist sand the counts come at a high rate and the motor turns the pointer through a small arc before stopping. With relatively dry sand the counts come more slowly and the motor, starting from zero, again turns through a larger arc before the required counts are collected. The dial can be calibrated in per cent of moisture. Tests indicated this system had an accuracy of better than ¼ per cent at the 90-per cent confidence level. This figure includes everything except the statistical error.

If the system error is ¼ per cent, the statistical error then can be as high as ¾ per cent. Using the reliable error formula, it is necessary to count at least 50,000 counts to be within ¾ per cent of the true count rate. To provide a safety factor and to better utilize the preset count features of the available scaler, it was decided to use a preset count of 100,000, which gives a reliable error of 0.52 per cent.

Another consideration was to design the system so the test could be performed without decreasing the muller output. This meant the 100,000 counts had to be collected and the moisture figure made available in less than one minute. This called for a system superior to the field test system which required two minutes to collect approximately 55,000 counts.

The count rate can be increased by either:

- Increasing the size of the source, or
- Increasing the number and the sensitivity of the thermal neutron detectors.

Increasing the strength of the source raises the costs of both the source and the required shielding. The number of detectors that can be added also is limited due to their high cost and the limited space in the access tube. Detector sensitivity can be improved to a certain extent by increasing the pressure of the filling gas.

Another design consideration was to select the proper neutron source and detectors.

There are no readily available radioisotopes that emit fast neutrons directly. To obtain neutrons from radioisotopes it is necessary to resort to indirect methods, which fall roughly into two categories: the photo-neutron reaction and the alpha-neutron reaction. In the photo-neutron method certain nuclei emit neutrons in the presence of very high energy gamma rays. This method is not generally used because of its poor efficiency and the intense gamma fields that result. The alpha-neutron method depends on the fact that certain target materials emit a neutron when their nucleus absorbs an alpha particle. Beryllium has the highest neutron yield and the reaction can be described as:

$$Be^9 + \alpha^4 \rightarrow n^1 + C^{12} + 5.76 \text{ mev.}$$

To fabricate a neutron source of this type it is necessary to mix as intimately as possible an alpha emitter with a suitable target material such as beryllium. The energy of the emitted neutron

MOISTURE CONTENT OF SAND COMPARISONS

	WITHOUT GAGE	WITH GAGE
TOTAL NUMBER OF SAMPLES	92	27
SAMPLES WITHIN ± 0.1 PER CENT OF STANDARD	41	27
SAMPLES WITHIN ± 0.05 PER CENT OF STANDARD	21	24
PER CENT SAMPLE WITHIN ± 0.1 PER CENT OF STANDARD	45	100
PER CENT SAMPLES WITHIN ± 0.05 PER CENT OF STANDARD	24	89

Table I—This table shows the results of tests made with the moisture gage and without the gage on the moisture content of the sand. The ± 0.1 per cent deviation from standard percentage moisture represents the results desired by the sand laboratory while the more stringent ± 0.05 per cent deviation was the requirement used in the design of the moisture gage.

is chiefly a function of the alpha particle energy, the reaction energy (5.76 mev in the equation above), the coulomb repulsion energy, and the alpha and neutron absorption properties of the source mixture. Such a source emits neutrons having a spectrum of energies up to about 10 mev. A plutonium-beryllium source was selected because of its low cost and long half-life of 24,000 years. It contains 2 curies of plutonium-239 and emits 2.8×10^6 neutrons per second. A pair of high sensitivity BF_3 proportional counters were selected to count the neutrons thermalized by the moisture in the sand. By using the selected source and the two detectors in a specially designed assembly (Fig. 3), which was installed in Central Foundry's Danville, Illinois, plant, it was possible to collect the 100,000 counts in the desired time.

Single Gage Controls Two Mullers in Operation Sequence

The system consists of two mullers located next to each other and controlled by the same operator (Fig. 4). Sand for the mullers comes from the same storage bin and the moisture gage is used in sequence to control each muller.

The weigh lorry is supported by a large scale. When 3,200 lb of sand are fed into the hopper, the electric feeder is shut off and the same relay starts the automatic operation of the moisture gage. The pointer on the computer, and the electronic and mechanical counters of the nuclear scaler, are reset to zero. After a momentary pause, the scaler starts counting and the computer starts simultaneously, thereby turning the indicator. When 100,000 neutrons have been counted, a relay in the scaler interrupts the power to the computer and the pointer indicates the moisture content of the sand in the weigh lorry. The circuits are interlocked so that the sand cannot be dumped from the weigh lorry until the count has been completed. When the operator presses the dump button, the sand falls into the muller, the electric feeder fills the weigh lorry again and the cycle continues.

A few seconds after the sand is dumped into the muller, the computer energizes a water valve. The measuring and adding of sufficient water to bring the sand's moisture content to the desired level is entirely automatic. Certain binding materials are now added to the sand in the muller. After a predetermined time, the moisture corrected sand is dumped onto an outgoing vibrator. An elevator and belt system then carries the sand to the casting line.

Tests have been conducted to compare the muller output using the new gage to the output under the former "feel" system (Table I). These tests showed the improvement achieved by the moisture gage and proved that the gage could satisfactorily keep the moisture content within the requirements of future castings.

Gaging and Control Process Produces Slight Moisture Content Variations

The slight deviation of the moisture content from the desired level stems from the accumulation of errors existing at various stages of the gaging and control process. The most dominating errors are:

(a) Statistical—The 100,000 counts collected result in a 0.5-per cent error at the 90-per cent level, giving a ± 1.5-degree error on the dial resulting in a ± 0.025-per cent moisture error

(b) Computer and Scaler—A series of tests indicate these comprise a total error of about ± ½ degree on the dial

(c) Sample Size—The performance of the nuclear system was judged on the basis of two 100-gram samples per batch. The only completely satisfactory method is to weigh and to oven dry the entire 3,200-lb charge as it comes from the muller, which is impractical.

Conclusion

The industrial health aspects of this project were continuously evaluated as the various investigations were undertaken. Members of the Industrial Hygiene Department of the Personnel Staff were frequently consulted. An evaluation of the final installation by this Department indicates that the system is completely safe as long as the source is inspected at frequent intervals and the relatively simple operating procedure is followed.

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GMR DYANA: The Computing System and its Applications

By BARRETT HARGREAVES
General Motors
Research Laboratories

Admittedly, a digital computer always has been able to perform problem-solving tasks at blinding speed. But, in the past, a considerable amount of time, not to mention mathematical skill and computer training, was required to prepare a problem in a suitable form for the computer. A recent development designed to shorten this preparation time is GMR DYANA, an automatic programming system. The DYANA language is problem oriented and uses terms that resemble the engineer's language. Thus, the engineer can learn to set up many of his own problems for solution by the computer. DYANA is designed primarily for the study of any system whose mathematical model is known to be identical in structure and form to the model of a spring-mass-damper system.

DYANA provides medium of communication between engineer and computer

SINCE THE first use of electronic digital computers there has been a continual effort to reduce the communication gap between the computer and the individual with a problem to be solved. Like any tool, the effectiveness of the computer is dependent upon the ease with which it can be used*.

The GMR DYANA (DYnamics ANAlyzer-Programmer) system is a recent computer programming development by the GM Research Laboratories. It is intended to provide a medium of communication between the engineer and the computer and to facilitate the use of the computer for a particular class of engineering problems. These are vibrational, electrical, and equivalent dynamics problems.

The effectiveness of the DYANA system is a result of the two components of the system and the role each plays in the solution of a problem. These components are the *programming language* and a set of computer instructions called the DYANA *compiler*.

The engineer uses the programming language to describe his problem in a form acceptable to the computer. This problem description is called the DYANA *program*. The program consists of a description of the vibrating system being investigated, a few mathematical expressions required to completely define the system, and a set of statements specifying the answers that are desired. In essence, a DYANA *program* is a declaration of a problem statement. It tells the computer what the problem is, but in no way does it prescribe how to solve the problem.

It is the role of the DYANA *compiler* to provide the solution to the problem. This it does by directing the computer to prepare a rigorous mathematical model of the problem, to set up the necessary numerical procedures for solving that model, and then to organize these procedures into a FORTRAN program. The subsequent execution of this FORTRAN program provides the desired answers. (A FORTRAN—FORmula TRANslator—program is a collection of expressions or statements which define a sequence of instructions for the computer. It is one of several available methods of manual programming using a language based on ordinary English and mathematical notation. Many of the FORTRAN expressions have an algebraic appearance.)

DYANA Uses a Problem Oriented Language

The DYANA programming language is representative of a stage in the evolution of computer languages. Initially, a person using a digital computer was required to perform the series of seemingly endless, minutely detailed operations of basic machine coding. Here all communication was at the lowest level of the machine logic. The coder used nothing but combinations of the binary bits 1 and 0. The computer hardware interpreted the binary language directly according to a prearranged code.

As the speed of computers and the size of programs increased, binary coding became too time consuming. To cope with the situation, a series of *symbolic programming* methods was devised. The programmer could relegate to the computer the task of translating alphanumeric symbols to the binary code the computer uses. The symbols used, however, were understood only by trained programmers. To obtain answers from the computer it was necessary to rely on a team effort between the engineer with his problem and the programmer.

The next major programming development after symbolic coding was the *algebraic translator*. Here the programmer or specially trained engineer could write equations for the computer in a form of algebra. In the FORTRAN system, for instance, the equation

$$F_T = X_1a_1 + X_2a_2$$

might be coded

$$FORCET = X(1)*ACCEL(1) + X(2)*ACCEL(2).$$

These algebraic statements were processed by the computer through a series of translations down to the basic binary code.

All of the programming methods described thus far are predominately computer oriented and general in purpose. Computer oriented means that the method is designed with the computer as a starting point and developed toward the user. The result is, of course, that the language of communication retains much of the computer dialect. Memory assignments must be made, input and output formats must be selected and coded, and a proper sequence of coding is imperative. Because these programming lan-

*For readers who may desire background information on computer fundamentals, there are numerous references available in texts and from manufacturers of computer equipment. A suggested reference in a back issue of the JOURNAL is: "What Is a Digital Computer?" by Donald E. Hart, Vol. 5, No. 2, April-May-June 1958.

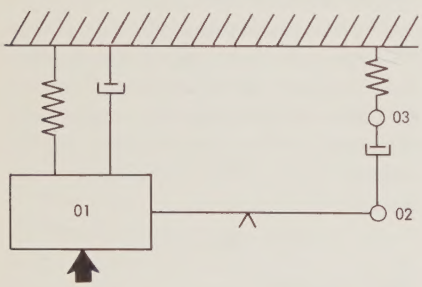
guages are of a general purpose, there is a translation that must be made between the problem at hand and the language of the programming system.

A more recent development in digital computer programming languages is the *problem oriented language*. In this case, the vocabulary of the language is restricted to a specific area of computer application, and the language is developed from the area of study toward the computer. The GMR DYANA system has a language which can be classified as a problem oriented language.

The DYANA system, being restricted to certain dynamics problems, has a language which is closer to the engineer's language than the previous types of coding languages. The DYANA language is intended to be sufficiently similar to the engineer's terminology to allow him, in many cases, to program his own problems, thus eliminating the programmer from the line of communication.

The DYANA Language is Used to State the Problem

The DYANA language can be explained by considering the following schematic diagram of a simple, spring-



mass-damper vibrating system. The vibrating system consists of a mass (square box) which is attached to ground by means of a spring and a damper. The mass also is connected through a lever, with a fixed fulcrum, to another damper. The latter damper is connected to a spring which, in turn, is connected to ground. A force (heavy arrow), applied to the mass, excites the system.

All points in the system at which two or more elements are connected are labeled with a unique two-digit number (other than *00*, which *always* represents a fixed ground point)—for example, *01*, *02*, and *03*. The purpose in assigning these numbers is to distinguish and identify each degree of freedom of the system by a unique label. This labeling is a primary requirement and, as shall be shown,

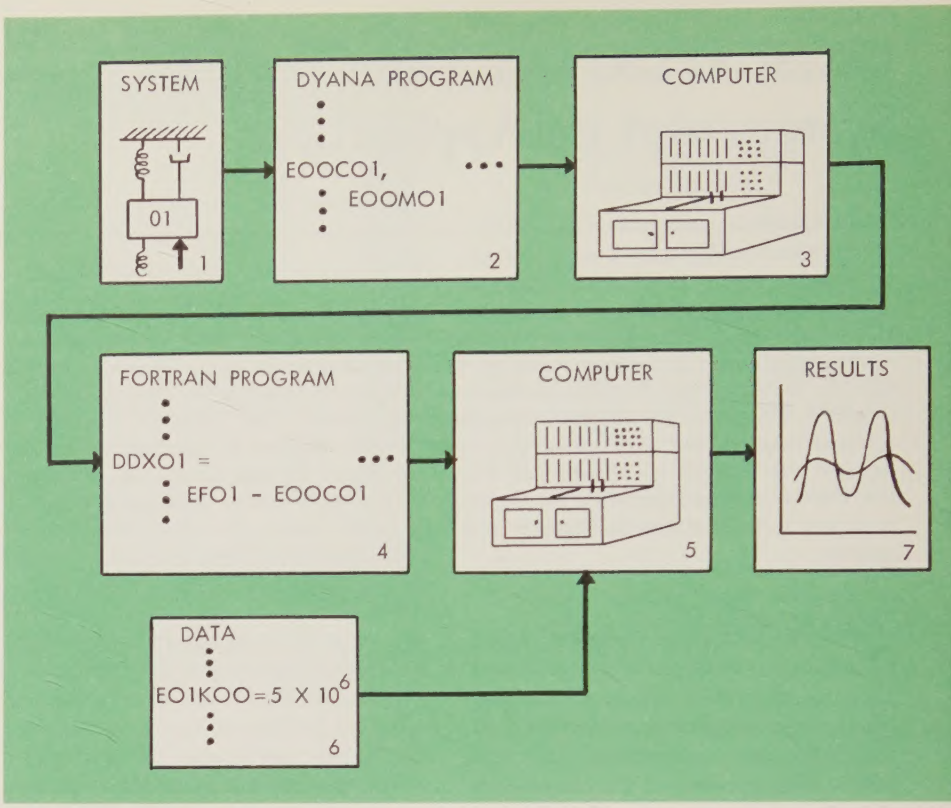


Fig. 1—This diagram represents the sequence of events in the DYANA solution of a problem, such as in a simple spring-mass-damper vibration system. Block *1* shows the engineer's original problem statement. Block *2* shows the DYANA program as it is submitted to the computer. Just before the DYANA program is read into the computer, the DYANA compiler (a set of computer instructions) is loaded into the computer and given control. Block *3* represents the compile operation. Block *4* represents the FORTRAN program which actually consists of a deck of IBM cards and a printed listing of the program generated by DYANA. Block *6* represents the numerical data values submitted for solution. The final step is the printing and plotting of results, Block *7*. The appearance of two distinct computers in the diagram (Blocks *3* and *5*) does not mean that two computers are involved. Only one is used. The separate computers are intended to distinguish between the two functions of the computer. In the first instance, the computer acts as an analyzer-programmer, while in the second, it performs in its normal capacity as an arithmetical calculator. When the engineer becomes familiar with the DYANA data specification requirements, he may submit his problem description and his data sheet together and receive his answers in only one pass through the computer.

forms the basis for writing the DYANA program.

A typical problem associated with the above vibrating system might be the following: Determine, as a function of time and in the vertical direction, the acceleration of point *01*, the velocity of point *02*, and the displacement of point *03*. Assume that the force which excites the system is given by the equation:

$$F_1 = 650.2 \sin(\pi t).$$

The following statements represent a DYANA expression of the problem:

```
X  SYSTEM DESCRIPTION
     E00K01, E00C01, E00M01, E01N02,
     E02C03, E03K00, EF01

X  FORCE EF01
     EF01 =650.2*SINF (3.1416*TIME)

X  PRINT-PLOT ANSWERS
     X03, DX02, DDX01, VS. TIME
```

The computer is then directed to set up the differential equations resulting from the system description. For the simple vibration system described above, these equations are:

$$(E00M01)\frac{d^2x_1}{dt^2} + (E00K01)\,x_1 + (E00C01)\frac{dx_1}{dt} + F = EF01$$

$$E02C03\left(\frac{dx_2}{dt} - \frac{dx_3}{dt}\right) - \left(\frac{1}{E01N02}\right)F = 0$$

$$E02C03\left(\frac{dx_3}{dt} + \frac{dx_2}{dt}\right) + (E00K03)\,x_3 = 0$$

$$X_1 - \left(\frac{1}{E01N02}\right)X_2 = 0.$$

The reaction force exerted on points *01* and *02* due to small deflections of the lever is represented by *F*. When used in these equations, the symbol *E01N02* takes on the meaning: the lever ratio r_2/r_1; where r_1 is the distance from the fulcrum to point *01*, and r_2 is the distance from the fulcrum to point *02*.

After the differential equations have been established, the DYANA compiler directs the computer to analyze the equations and establish a sequence of numerical procedures which will insure a solution for:

$$\frac{d^2x_1}{dt^2}, \frac{dx_1}{dt^2}, x_1, \frac{dx_2}{dt}, x_2,$$

$$\frac{dx_3}{dt}, x_3, \text{ and } F.$$

The statements representing the DYANA expression of this problem describe the system being studied, specify the value of the exciting force, prescribe the answers to be solved for, and state the mode in which the computer is to produce the answers.

The meaning of the individual statements is as follows: X SYSTEM DESCRIPTION indicates that the symbols appearing in the subsequent statements up to the next X statement describe the schematic. Thus, *E00K01* means that there is a spring (*K*) which is connected between point *01* and ground (*00*). *E00M01* indicates a mass (*M*) at point *01*. The *N* of *E01N02* denotes a lever. *E02C03* refers to the damper between points *02* and *03*. *EF01* denotes a force at point *01*. To define the nature of the forcing function, the statement X FORCE, *EF01*, is used followed by a FORTRAN expression for the equation for F_1.

The final two statements of the DYANA program indicate that a plot is desired of the displacement of point *03* (*X03*), the velocity of point *02* (*DX02*), and the acceleration of point *03* (*DDX03*) versus time.

An engineer studying this vibrating system writes down the DYANA statements and submits them to a computer installation for keypunching and compilation.

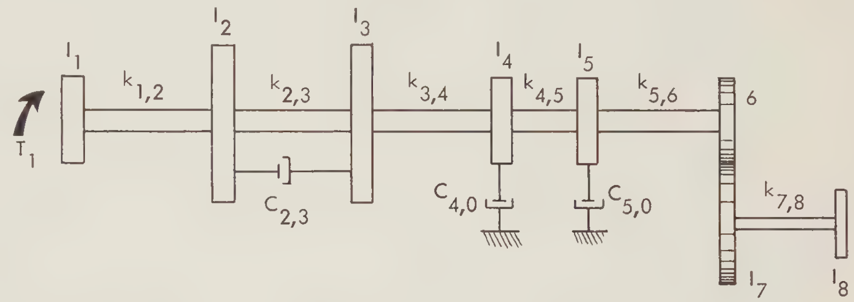
DYANA Compiler Analyzes Problem Statement and Generates Computer Program

The compiler represents the second major component of the DYANA system. The compiler directs the computer to scan and analyze the incoming statements of the DYANA program.

Here the compiler performs the functions of a programmer. It determines the number and order of the equations involved for the differential equation subroutine. It checks for nonlinearities or discontinuities that will affect the sequence of the numerical solution. Finally, in the analysis section of the compiler, the computer decides which additional subroutines are required to perform functions such as: matrix inversion, solution of simultaneous equations, and iteration for points of discontinuities.

After the programming function of the compiler has been completed, the differential equations, the subroutine requirements, and the output specifications are coded by the computer into a FORTRAN program. The FORTRAN program takes the form of a deck of IBM cards and a printed listing of the FORTRAN program generated by DYANA. The engineer also will receive a data specification guide listing the exact form in which the parameter values must be presented.

The engineer submits a data sheet on which is written the values of his system parameters, any initial conditions other than zero, and the range of the independent variable over which he desires a solution. These data, together with the FORTRAN program, are submitted to the computer for solution. In the concluding steps of the problem solution sequence, the computer performs the mathematical operations and produces plotted and printed results (Fig. 1).



STATEMENT NUMBER 1 5	CONTINUATION 6	DYANA PROGRAM 7 72	IDENTIFICATION 73 80
X		SYSTEM DESCRIPTION	
		EOOMO1, EOOMO2, EOOMO3, EOOMO4, EOOMO5	
		EOOMO7, EOOMO8, EO1KO2, EO2KO3, EO3KO4	
		EO4KO5, EO5KO6, EO7KO8, EO6NO7	
		EO2CO3, EOOCO4, EOOCO5, EFO1	
X		PRINT-PLOT ANSWERS	
		AMPLO1, AMPLO2, VS. FREQ	
		AMPLO3, AMPLO5, VS. FREQ	
		AMPLO8, VS. FREQ	

EOOMO1 = INERTIAL ELEMENT AT POINT 1
EO1KO2 = TORSIONAL SPRING (SHAFT) BETWEEN POINTS 1 AND 2
EO2CO3 = TORSIONAL DAMPER BETWEEN POINTS 2 AND 3
EO6NO7 = GEAR SET CONNECTING POINTS 6 AND 7
EFO1 = SINUSOIDAL TORQUE AT POINT 1
AMPLO1 = AMPLITUDE (AMPL) OF THE DISPLACEMENT OF POINT 1
FREQ = FREQUENCY OF THE TORQUE AT POINT 1 IN CYCLES PER SEC

Fig. 2—DYANA is especially adaptable to the study of torsional systems. An example of such a system is the drive line represented by the free body diagram shown at the top. Inertias are identified by the symbol *I* at various points. Similarly, dampers are identified by *C* and shafts by *k*. The treatment of the gears is such that the gear on shaft $k_{7,8}$ has an inertial value while the inertia of the other gear is neglected. The typical problem in this system is the determination of the steady state amplitudes of inertias *1*, *2*, *3*, *5*, and *8* as the frequency of a sinusoidal torque acting on inertia *1* varies from 5 cps to 400 cps. The solution of the problem begins with the writing of the DYANA program, as shown. Variables appearing in the program are defined in the listing shown below the DYANA program.

The Scope of DYANA

The DYANA system was designed primarily for the study of spring-mass-damper systems. Because of the well-known analogies that exist between translational dynamic systems, electrical networks, and heat transfer systems, the DYANA compiler can be used to advantage in any of these types of problems. Any problem, in fact, whose mathematical model is known to be identical in structure and form to the mathematical model of spring-mass-damper systems can be mapped directly into the DYANA language for solution.

On the other hand, the DYANA system has in its vocabulary statements that will permit the engineer to write, in FORTRAN, differential equations describing problems that cannot be easily mapped into a system description. The DYANA system will, in this case, generate a FORTRAN program incorporating the proper calling sequence to an integration subroutine, necessary computer memory assignments, and input-output coding as required.

The original DYANA system can set up equations for any system in which the motion of node points is free to move with one degree of freedom and is independent of other degrees of freedom. More complex systems with interdependent degrees of freedom can be studied using an extended DYANA system recently developed. This application is described in the paper beginning on page 14 of this issue.

Two Kinds of Solutions: Transient or Frequency Response

The DYANA system can be directed to produce a computer program for either a transient analysis or a frequency response analysis. The transient (time varying) solution yields instantaneous displacements, velocities, and accelerations as time progresses through a specified period. Forcing functions may, in general, be defined in terms of known displacements, velocities, accelerations, or forces. Parameters may be described which have nonlinear or discontinuous characteristics. The time varying solution will yield a complete time history, if required, revealing the circuit response in its transient and subsequent steady state condition.

The frequency response program generated by DYANA uses the Laplace transform of the differential equations with $j\omega$ substituted for the Laplace variable. The computer solves the resulting complex linear algebraic equations for the amplitude and phase angle of every point in the system as frequency is varied over a range. This type of DYANA program is restricted to linear systems but can be used effectively to study resonant conditions.

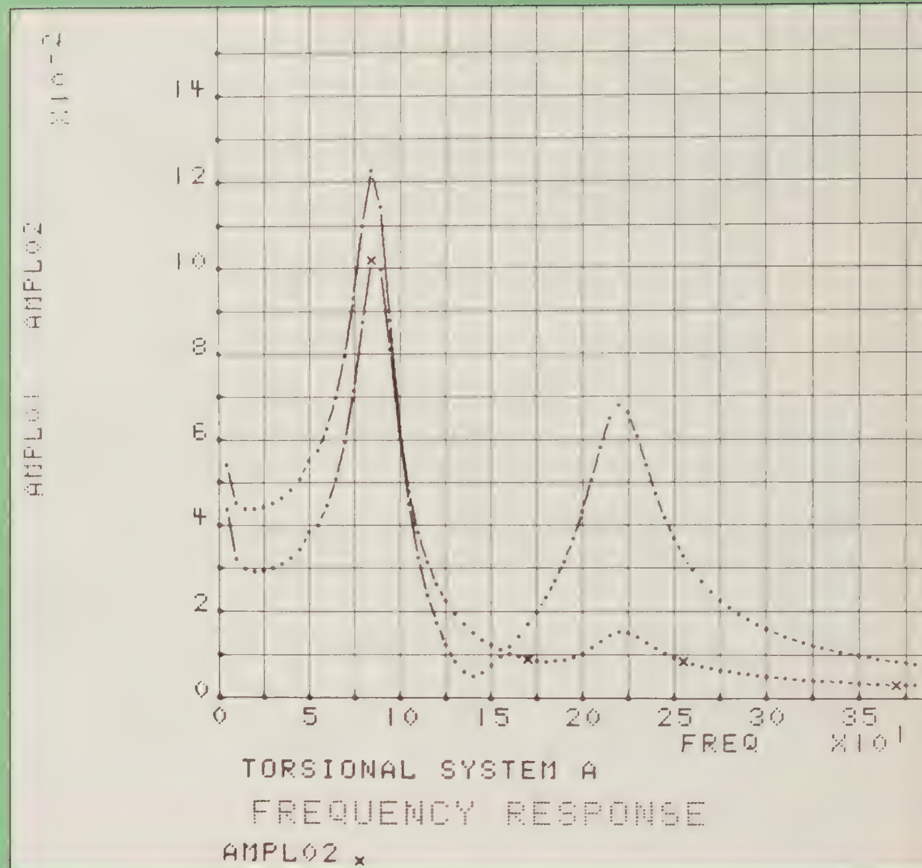


Fig. 3—The results of the problem described in Fig. 2 are given by this plot of the frequency response of the torsional system. This is a reproduction of the form in which the computer produces the plot.

Two examples of typical problems which have been solved using DYANA will illustrate its features.

A Torsional System Problem

A typical problem in automotive design, which is applicable to the DYANA system, is found in the study of crankshafts, transmissions, and drive lines. This type of problem can be represented by a torsional system, containing a number of inertias, dampers, and shafts (Fig. 2). The system also may be a branched one with a gear set connecting the shafts. The typical problem encountered in a torsional system is the determination of the steady state amplitudes of points in the system as the frequency of a sinusoidal input torque varies over a range.

The essential step in the solution of this type of problem is the preparation of a DYANA program (Fig. 2). This program consists of a total of nine statements. The first five describe the system. The remainder specify the precise output to be produced.

The DYANA compiler generates a FORTRAN program which then is executed using appropriate data values. The result is a frequency response plot of the

torsional system, produced by the computer (Fig. 3).

An important feature of the DYANA system is the difference in types of plots that are available. By proper inclusions of the words LOG or POLAR in the statements describing the variables to be plotted, plots will be produced which are either logarithmic (one or both axes), or polar. Each plot produced by the DYANA system will be accompanied by a tabulated listing of the points that were plotted.

The frequency response program just considered demonstrates the use of a few of the fundamental statements of the DYANA language. These few, however, were adequate to obtain a solution to a rather complex torsional problem.

A Suspension System Problem

The complexity of the previous problem was due mainly to the size of the system involved. A more serious type of difficulty arises when a non-linear or discontinuous system is encountered. To simplify the treatment of such systems the DYANA language includes 20 different types of X statements. The use of a few of these statements can be demonstrated in a typical problem involving a portion of a vehicle suspension system. Included in the system are a tire spring rate, a wheel and tire mass, a non-linear suspension spring, a shock absorber, and an effective body mass (Fig. 4). The problem is to determine the body and wheel response of the vehicle as a function of the distance it travels.

The system is both discontinuous and non-linear. It is discontinuous in the sense that the excitation supplied to the system consists of two distinct parts. Both of these parts are specified in terms of the analytic expressions (Fig. 4). The non-linearity of the system is due to the pneumatic character of the main suspension spring. The rate of the spring depends upon the amount of compression or rebound it experiences and is given by the equation

$$k_{1,2} = \frac{AP_o}{(x_1 - x_2)}\left[1.0 - \left(\frac{V_o}{V_o + (x_1 - x_2)A}\right)^{\gamma}\right]$$

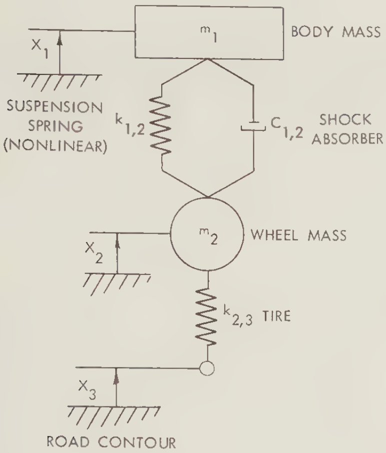
where

P_o = initial pressure of the cylindrical air chamber

V_o = initial volume of the cylindrical air chamber

A = cross sectional area of the air chamber

γ = specific heat ratio.



RANGE 1 - $X_3 = A(1 - \cos \frac{2\pi vt}{\ell})$; $0 \leq$ DIST. $\leq \ell$

RANGE 2 - $X_3 = 0$; $\ell <$ DIST.

WHERE

ℓ = LENGTH OF BUMP

v = VEHICLE VELOCITY

STATEMENT NUMBER (1–5)	CONTINUATION (6)	DYANA PROGRAM (7–72)	IDENTIFICATION (73–80)
X		SYSTEM DESCRIPTION	1
		EOOMO1,EO1KO2,EO1CO2,EOOMO2,EO2KO3,XO3	2
X		READ INPUT VARIABLES	3
		AREA, PNAUT, VNAUT, GAMMA, AMPL, V, L	4
X		SPRING RATE, EO1KO2	5
		EO1KO2 = AREA/(XO1 - XO2)*PNAUT*(1.0-(VNAUT/	6
	1	(VNAUT + (XO1 - X)2)*AREA))**GAMMA)	7
X		DISPLACEMENT, XO3, RANGE (1)	8
		XO3 = AMPL*(1.0 - COSF(6.28318*V/L*TIME)	9
X		DISPLACEMENT, XO3, RANGE(2)	10
		XO3 = 0.0	11
X		RANGE FUNCTIONS	12
		DIST = V*TIME	13
		RANGE(1) = L - DIST	14
		RANGE(2) = DIST - L	15
X		PRINT-PLOT ANSWERS	16
		XO3,XO1, VS. DIST	17
		XO2,XO3, VS. DIST	18

Fig. 4—Another application of DYANA is in the study of vehicle suspension systems. The problem is to find the body and wheel response of the vehicle as a function of the distance it travels. The diagram at the top represents a simplified suspension system. The analytic expressions with the diagram specify the two distinct parts of the excitation that is supplied to the suspension system. At the bottom is the DYANA program for the solution of the problem. The appearance of *X03* in statement *2* is the convention of the language for expressing the condition that point *03* is to be excited by a known displacement (the road contour). The use of statements *3* and *4* allows those variables that are not listed in the system description to have their values assigned at the time data cards are prepared. The treatment of the non-linear spring rate is shown in statements *5*, *6*, and *7*. To express the discontinuous nature of the road wave, statements *8* through *15* are required. The appearance of the symbols *RANGE* (*1*) and *RANGE* (*2*) in statements *8* and *10* specify that the subsequent excitations are to be used only when the vehicle is in that range. The two ranges are defined in terms of algebraic expressions by statements *12* through *15*. Statements *8* through *15* convey to the DYANA compiler the same information as is contained in the two analytic expressions for the excitation.

A DYANA program to provide a solution to the problem is written as shown in Fig. 4. Some different types of X statements also are shown and explained. Numerical values are fed into the computer for solution, and the result is a computer plot of the wheel response curve (Fig. 5).

Additional Application of DYANA

The notation of the DYANA language and the ability of the compiler to produce equations based on that notation are very powerful and significant features. In fact,

these features make DYANA applicable to a wider class of problems than might be inferred from the examples considered so far. To illustrate this, consider the sequence of symbols:

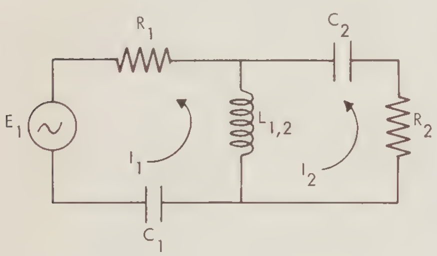
E00C01, *E01M02*, *E00K02*,

E00C02, *E00K01*, *and EF01*.

This sequence will cause the DYANA compiler to produce the following equations:

$$\left.\begin{aligned} &E01M02\left(\frac{d^2x_1}{dt^2}-\frac{d^2x_2}{dt^2}\right)+(E00C01)\frac{dx_1}{dt} \\ &\qquad +(E00K01)x_1 = EF01 \\ &E01M02\left(\frac{d^2x_2}{dt^2}-\frac{d^2x_1}{dt^2}\right)+(E00C02)\frac{dx_2}{dt} \\ &\qquad +(E00K02)x_2 = 0 \end{aligned}\right\} \quad (1)$$

For a simple electrical circuit, such as the following one,



the loop equations are:

$$\left.\begin{aligned} &L_{1,2}\left(\frac{di_1}{dt}-\frac{di_2}{dt}\right)+\frac{1}{C_1}\int i_1dt \\ &\qquad +R_1i_1=E_1 \\ &L_{1,2}\left(\frac{di_2}{dt}-\frac{di_1}{dt}\right)+\frac{1}{C_2}\int i_2dt \\ &\qquad +R_2i_2=0. \end{aligned}\right\} \quad (2)$$

Equations (1) have the same form as equations (2). They transform identically into equations (2) when the following equivalences are made:

$$\left.\begin{aligned} &E01M02 = L_{1,2} &\quad EF01 = E_1 \\ &E00C01 = R_1 &\quad x = \int idt \\ &E00K01 = \frac{1}{C_1} &\quad \frac{dx}{dt} = i \\ &E00C02 = R_2 & \\ &E00K02 = \frac{1}{C_2} &\quad \frac{d^2x}{dt^2} = \frac{di}{dt} \end{aligned}\right\} \quad (3)$$

Thus, a DYANA program which uses the preceding sequence of variables to describe a system, in fact, describes an RLC electrical circuit. By assigning data values in accordance with equivalence equations (3), such a program can be used to analyze the responses of that circuit.

An application of DYANA to an electrical problem can be illustrated by an equivalent circuit of a full-wave rectifier with a two-section choke input filter (Fig. 6). The input voltage E_1 is the rectified sinusoidal output from the rectifier as it is applied to the filter. The resistance R_3 represents a load for the d-c output. Assume that the engineer is interested in a plot of the output voltage from $t = 0$ to $t = 0.15$ sec, a time sufficient for the transients to die out so that the output voltage ripple can be observed.

The DYANA language is applied and a program written describing the problem (Fig. 6). The symbols listed under X SYSTEM DESCRIPTION define the circuitry. Statement numbers 4 through

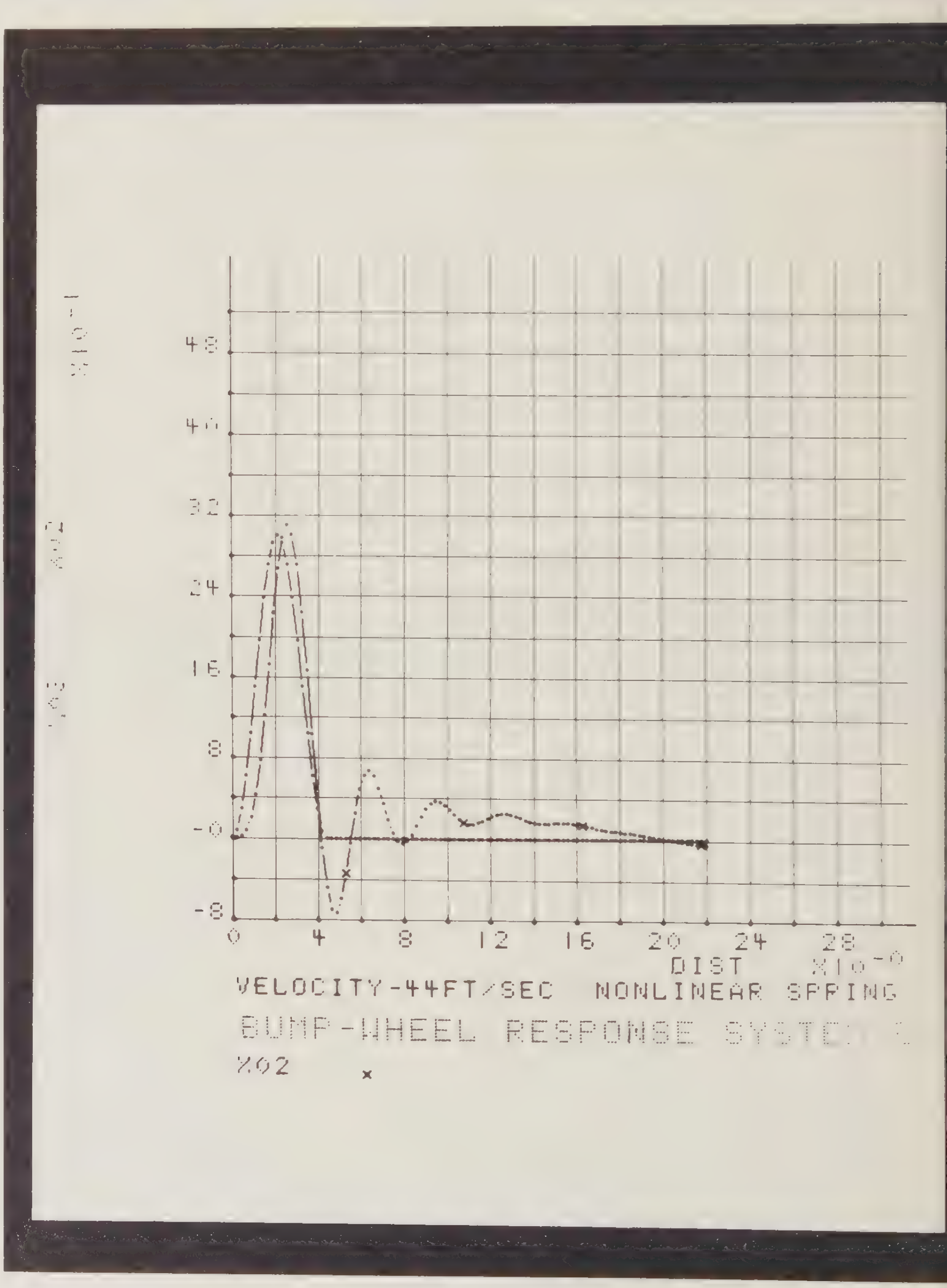


Fig. 5—Numerical values applying to the suspension system problem described in Fig. 4 are supplied to the computer, together with FORTRAN expressions, to produce a solution in the form of the wheel response curve shown here.

10 describe the segmented nature of the rectified input voltage.

The concept of range definitions can be used to express segmented characteristics of any of the system parameters. Inductor saturation, for instance, might be expressed by two equations for a *EaMb* type element, the range being dependent upon the current through the element. If the nonlinear element characteristics can not be conveniently broken down into segments, the parameter can be defined using an algebraic expression or a table of X, Y coordinate points of its characteristic curve.

Statement 11,

(X TIME DEPENDENT COMPUTATIONS),

and statement 12,

($VOUT$ = $DX03*E00C03$),

of the program are used to compute the output voltage from the loop current. Statement 12 is the FORTRAN expression for

$$V_o = \frac{dq_3}{dt} R_3.$$

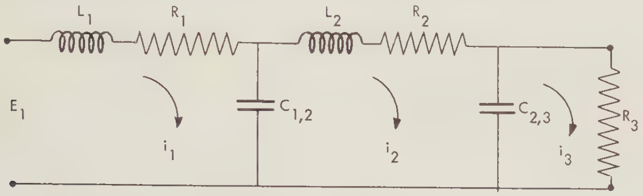
The computer plot shows the transient response of the rectifier circuit resulting with all initial conditions set to zero. From the plot the engineer can see the time required for the transients to subside and the general nature of the output voltage compared to the rectified input signal. A study of the printed output will allow a more detailed analysis of the voltage ripple.

Conclusions

Computing answers using a modern high-speed computer is just a small part of the problem solution. Other steps in the solution, such as analyzing the problem and translating it into computer language, have become much more imposing and time consuming. To make up this lag, people in the computer field have been trying recently to turn over to the computer more and more steps in the solving of a problem. They have, for example, greatly reduced the amount of manual programming through use of special intermediary languages like FORTRAN, which are based on ordinary English and mathematical notation.

Going beyond these initial efforts is DYANA. For large classes of dynamics and equivalent systems, DYANA permits the computer to perform automatically not only the computation associated with a problem but also the programming and the major part of the analytical work needed in setting up the problem. Thus, it eliminates the painstaking effort now involved in programming, coding, and "debugging" a computer program. It also simplifies the analysis of a physical system to a point where a simple description and a few mathematical expressions are usually sufficient. As a result, setup time for a typical problem has been reduced by a factor of as much as eight to one.

DYANA is an example of a problem oriented language and its associated computer procedure. In the future many more problem solving procedures of this type will be developed which will enable computers to carry out routine tasks presently being performed by technically trained people.



STATEMENT NUMBER (1–5)	CONTINUATION (6)	DYANA PROGRAM (7–72)	IDENTIFICATION (73–80)
X		SYSTEM DESCRIPTION	1
		EOOLO1, EOORO1, EFO1, EO1CO2	2
		EOOLO2, EOORO2, EO2CO3, EOORO3	3
X		FORCE, EFO1, RANGE(1)	4
		EFO1 = 424.0*SINF(377.0*TIME)	5
X		FORCE, EFO1, RANGE(2)	6
		EFO1 = -424.0*SINF(377.0*TIME)	7
X		RANGE FUNCTIONS	8
		RANGE(1) = SINF(377.0*TIME)	9
		RANGE(2) = -RANGE(1)	10
X		TIME DEPENDENT COMPUTATIONS	11
		VOUT = DXO3*EOORO3	12
X		PRINT-PLOT ANSWERS	13
		EFO1, VOUT, VS. TIME	14

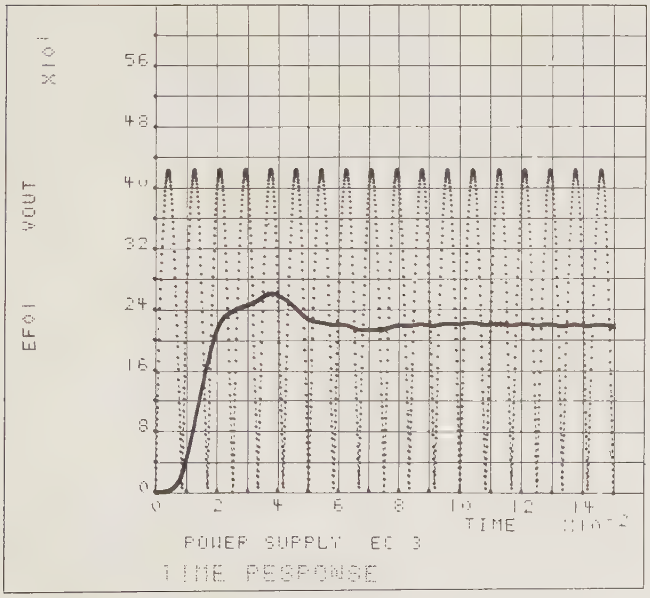


Fig. 6—Another application of DYANA is illustrated in an electrical problem involving a rectifier filter circuit (top). The problem is to obtain a plot of the output voltage for the time period from $t=0$ to $t=0.15$ sec, this time being sufficient for the transients to die out so that the output voltage ripple can be observed. The problem is described by the DYANA program (center). Statements *11* and *12* are used to compute the output voltage from the loop current. The computer plot (bottom) shows the transient response of the circuit with all initial conditions set to zero. The engineer can study the printed answers for a more detailed analysis of voltage ripple.

GMR DYANA: Extending the Computing System to Solve More Complex Problems

The GMR DYANA computing system was developed primarily to study dynamics problems frequently encountered in the work of the engineer. It also has the feature of shortening and simplifying the task of communications between the engineer and the computer. Originally, DYANA required that each of the individual elements of a dynamics system be restricted to one mode of motion. Sometimes, however, this restriction could not be met and still obtain a satisfactory solution to the problem. Thus, there was a need to extend the computing system to accommodate more complex situations. This is now being done by modifying DYANA to accept holonomic constraints (equations relating position coordinates) in the problem description. The constraint relations are expressed in the FORTRAN language and the DYANA system performs the required analytic differentiation of the expressions.

THE TWO principal components of the GMR DYANA computing system—the language and the compiler—have been described in the preceding paper beginning on page 7. In discussing the range and applicability of this system, it was noted that DYANA was limited to dynamics systems in which the modes of motion were independent.

A more recent development by the General Motors Research Laboratories is the modification of the DYANA compiler to accept holonomic constraints (equations relating position coordinates) in the description of a dynamics problem. Through the use of constraints, the modes of motion of a dynamics system no longer are required to be independent. This means a more complex type of problem can be solved easily by the computer.

Dynamics problems with constraints have been solved in the past using the original DYANA system. But, in most cases, a person trained in digital computer programming was needed to set up the problem. With the recent modifications to the DYANA compiler, it now is possible for a person with a minimum amount of training in the use of digital computers to solve dynamics problems with constraints. These modifications currently are being completed by the GM Research Laboratories and the extended system will be available for operation in early 1961.

How Constraints Are Used in Dynamics Problems

The use of constraints in dynamics problems may be illustrated by first examining elementary systems and then placing additional conditions on the problem solutions by means of constraints. Consider, for example, three particles of mass, m_1, m_2, and m_3, which are allowed to move in the x_1, x_2, and x_3 directions respectively. If a force is applied to each particle in the direction of the allowed motion, the associated equations of motion are the following:

$$\left.\begin{aligned} m_1\ddot{x}_1 &= F_1 \\ m_2\ddot{x}_2 &= F_2 \\ m_3\ddot{x}_3 &= F_3. \end{aligned}\right\} \quad (1)$$

These three equations are completely independent and give rise to the following solutions:

$$\left.\begin{aligned} x_1 &= x_1(t) \\ x_2 &= x_2(t) \\ x_3 &= x_3(t). \end{aligned}\right\} \quad (2)$$

A different interpretation could be attached to equations (1) and the solution equations (2) if m_1, m_2, and m_3 were defined to be the *mass* components in the x_1, x_2, and x_3 directions, respectively, of a particle. In this case, if x_1, x_2, and x_3 are mutually perpendicular, the solution equations (2) give the coordinates of the particle at each instant of time in a three-dimensional space. The motion of the single particle then can be plotted (Fig. 1). This particle can be considered to have three degrees of freedom and such a system may be represented in the original DYANA computing system.

DYANA heretofore has required that the motion in prescribed directions be independent, but in many dynamics problems this condition cannot be met. Therefore, interaction is introduced through the use of constraints. Consider, for example, the previous particle which may be required to move in the following plane:

$$P(x_1,x_2,x_3) = a_1x_1 + a_2x_2 + a_3x_3 - a_4 = 0. \quad (3)$$

Equations (1) no longer describe the motion of the particle unless the reaction force due to the plane is included. Viewing the plane as a surface in the x_1, x_2, and x_3 coordinate system, the reaction force must act in a direction normal to the plane. If λ is used to denote the reaction force, the components of this force in the x_1, x_2, and x_3 directions are obtained as follows:

Component of λ in the x_1 direction

$$= \frac{1}{r}\left[\frac{\partial P(x_1,x_2,x_3)}{\partial x_1}\right]\lambda$$

$$= \left(\frac{a_1}{r}\right)\lambda.$$

Component of λ in the x_2 direction

$$= \frac{1}{r}\left[\frac{\partial P(x_1,x_2,x_3)}{\partial x_2}\right]\lambda$$

$$= \left(\frac{a_2}{r}\right)\lambda.$$

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The improvement: constraints may be used in the description of a dynamics problem

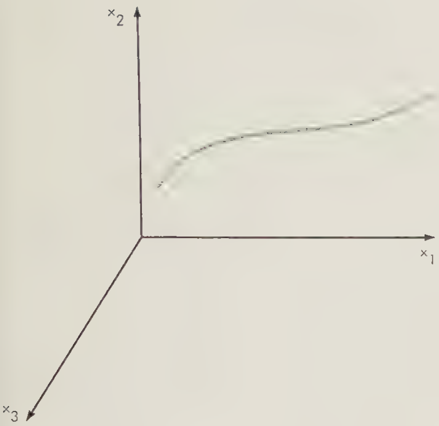


Fig. 1—This curve represents the motion of a particle of mass with more than a single degree of freedom. This particle is moving in three-dimensional space—x_1, x_2, x_3 coordinate system.

Component of λ in the x_3 direction

$$= \frac{1}{r}\left[\frac{\partial P(x_1,x_2,x_3)}{\partial x_3}\right]\lambda$$

$$= \left(\frac{a_3}{r}\right)\lambda$$

where

$$r = \sqrt{\left(\frac{\partial P(x_1,x_2,x_3)}{\partial x_1}\right)^2 + \left(\frac{\partial P(x_1,x_2,x_3)}{\partial x_2}\right)^2 + \left(\frac{\partial P(x_1,x_2,x_3)}{\partial x_3}\right)^2}$$

$$r = \sqrt{a_1^2 + a_2^2 + a_3^2}.$$

The quantities

$$\frac{a_1}{r}, \frac{a_2}{r}, \text{ and } \frac{a_3}{r}$$

are the direction cosines of the force which acts normal to the plane. Including the reaction forces in equations (1), the following equations are obtained:

$$\left.\begin{aligned} m_1\ddot{x}_1 + \frac{a_1}{r}\lambda &= F_1 \\ m_2\ddot{x}_2 + \frac{a_2}{r}\lambda &= F_2 \\ m_3\ddot{x}_3 + \frac{a_3}{r}\lambda &= F_3. \end{aligned}\right\} \quad (4)$$

Since the reaction force λ is unknown, an additional equation must be included with equations (4) to obtain a solution. The required equation in this case is the second derivative of the equation of the plane. The complete set of equations associated with a particle of mass constrained to move in a plane is as follows:

$$\left.\begin{aligned} m_1\ddot{x}_1 + \frac{a_1}{r}\lambda &= F_1 \\ m_2\ddot{x}_2 + \frac{a_2}{r}\lambda &= F_2 \\ m_3\ddot{x}_3 + \frac{a_3}{r}\lambda &= F_3 \\ a_1\ddot{x}_1 + a_2\ddot{x}_2 + a_3\ddot{x}_3 &= 0. \end{aligned}\right\} \quad (5)$$

The solution to this problem, throughout a given time range, can be illustrated by showing the path of the constrained particle of mass moving in the plane (Fig. 2).

The basic principles involved in obtaining equations (5) can be shown to apply generally to the solution of a large class of dynamics problems. The set of constraints which may be used to define the relationships among the degrees of freedom of the system have the following form:

$$f(x_1, x_2, \ldots, x_m, t) = 0 \quad . \qquad (6)$$

where $x_1, x_2, \ldots, x_m$ are the degrees of freedom of the system. A constraint of this form can be viewed as a surface in n-dimensional space. The reaction force associated with the surface must act in a direction that is normal to the surface. The steps leading to a set of equations for a constrained dynamics system can then be summarized as follows:

(a) The equations of motion are written for the dynamics system assuming that all the modes of motion of the system are independent

(b) The components of the reaction forces, due to the constraints, are obtained along each axis in the n-dimensional space and introduced in the appropriate equations of motion. Since the reaction forces are normal to the constraining surfaces, partial differentiation is required to obtain the force components

(c) The set of equations is completed by using the constraint relations or one of their derivatives as the situation requires.

One of the features of the original DYANA computing system is its ability to generate the equations of motion for a dynamics system on the basis of a system description. Since the equations of motion also are required in the solution of constrained systems, the basic approach to problem solution is not changed in the extended DYANA system. The primary addition in the extended DYANA system is the ability to do analytic differentiation of FORTRAN expressions. Each constraint relation is written in the FORTRAN language and the extended DYANA system generates the derivatives and partial derivatives that are required in setting up the equations for a constrained dynamics system. By doing the differentiation itself, the extended DYANA system requires only the minimum amount of information about a problem, and a computer program for

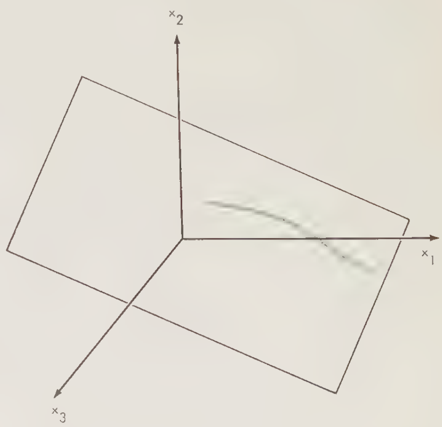


Fig. 2—The solution to the problem of describing the motion of a particle constrained to move in a plane is shown by this curve in the plane.

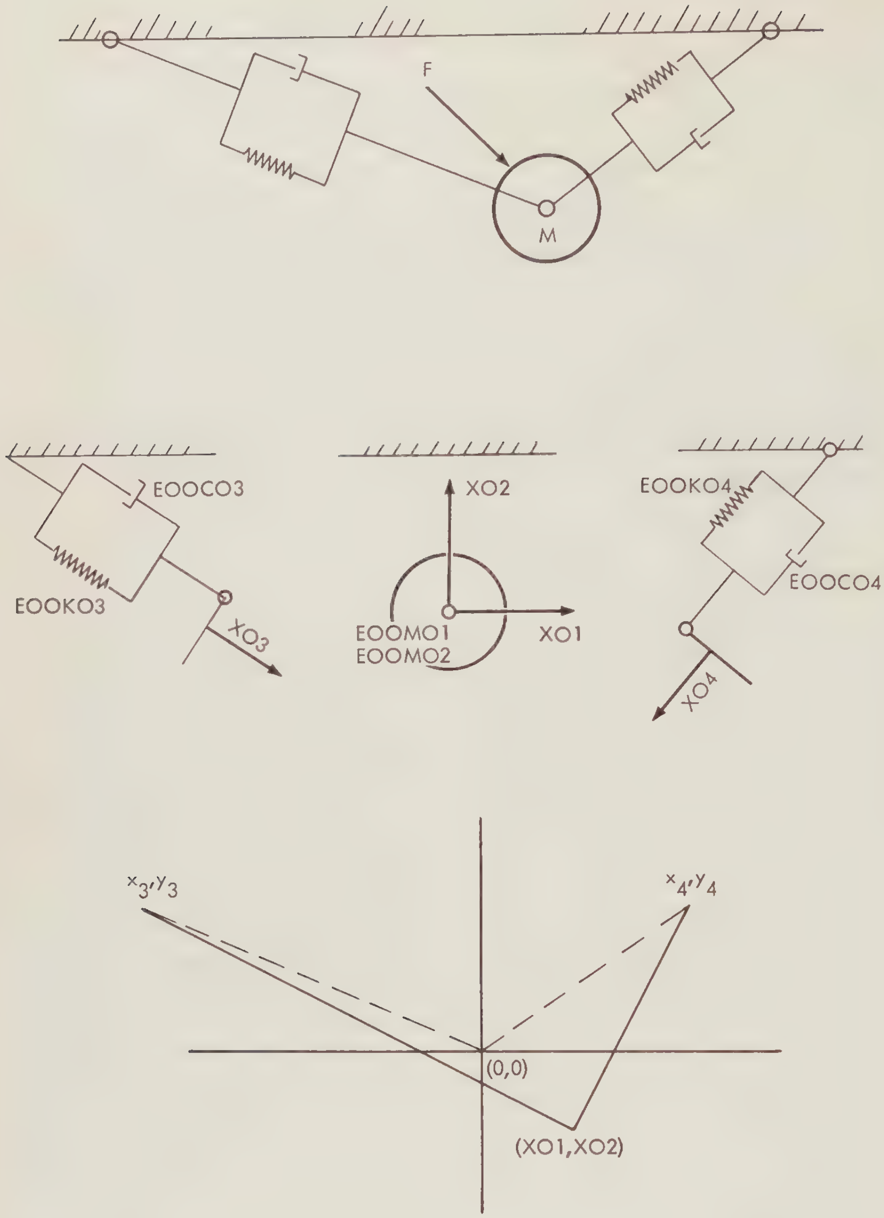


Fig. 3—A schematic of the mass-spring-damper system in Problem No. 1 is shown in (a). The problem to be solved is to find the motion of the mass when a force *F* is applied to the system. The mass has two degrees of freedom: horizontal and vertical displacement, denoted in DYANA language by *X01* and *X02*, respectively (b). *X03* and *X04* denote the degrees of freedom of the spring damper pairs. Assuming that *X01*, *X02*, *X03*, and *X04* are independent parameters, the system in (a) can be divided into the three sub-systems shown in (b). The elements of these systems are identified in DYANA language. The constraints which relate the motions of the sub-system are determined from an arbitrary displacement of the mass from point (*0*, *0*) to point (*X01*, *X02*), as shown in (c).

the solution of the problem can be produced quickly and efficiently.

Additions to DYANA Language Describe Constraint Problems

How a typical constrained dynamic system is described in DYANA language can be illustrated by three problems dealing with: a mass-spring-damper system, a single cylinder engine, and a double pendulum. With the exception of the DYANA statement,

X CONSTRAINTS,

the DYANA programs of the extended computing system are identical to programs written for the original DYANA system.

Problem No. 1: Mass-Spring-Damper System

Consider a mass-spring-damper system in which a mass m is connected to ground through two spring-damper pairs (Fig. 3a). The springs and dampers are connected to the mass and ground by means of hinges. The problem is to find the motion of the mass when a force F is applied to the system.

Two degrees of freedom are associated with the mass: horizontal and vertical displacement, which may be denoted in DYANA language by *X01* and *X02*, respectively. Since the spring-damper pairs do not act in the *X01* and *X02* directions, the amount of their compression or expansion will be measured in terms of the degrees of freedom *X03* and *X04*. Assuming that *X01*, *X02*, *X03*, and *X04* are independent parameters, the original system can be divided into the three sub-systems (Fig. 3b).

The elements of the sub-systems are identified in terms of DYANA notation, and these sub-systems are described to DYANA by listing the elements. The constraints which relate the motions of the sub-systems are determined from an arbitrary displacement of the original system (Fig. 3c).

The points (x_3, y_3) and (x_4, y_4) correspond to the ground connections of the spring-damper pairs and the point (*X01*, *X02*) is the position of the mass. Since the mass was initially at the point (0,0), *X01*, *X02*, *X03*, and *X04* are related as follows:

$$X03 = \sqrt{(X01 - x_3)^2 + (X02 - y_3)^2} - r_3$$

$$X04 = \sqrt{(X01 - x_4)^2 + (X02 - y_4)^2} - r_4$$

where

$$r_3 = \sqrt{x_3^2 + y_3^2}$$

$$r_4 = \sqrt{x_4^2 + y_4^2}.$$

The force F applied to the original system can be resolved into components in the *X01* and *X02* directions. In the DYANA language these component forces are denoted by *EF01* and *EF02*.

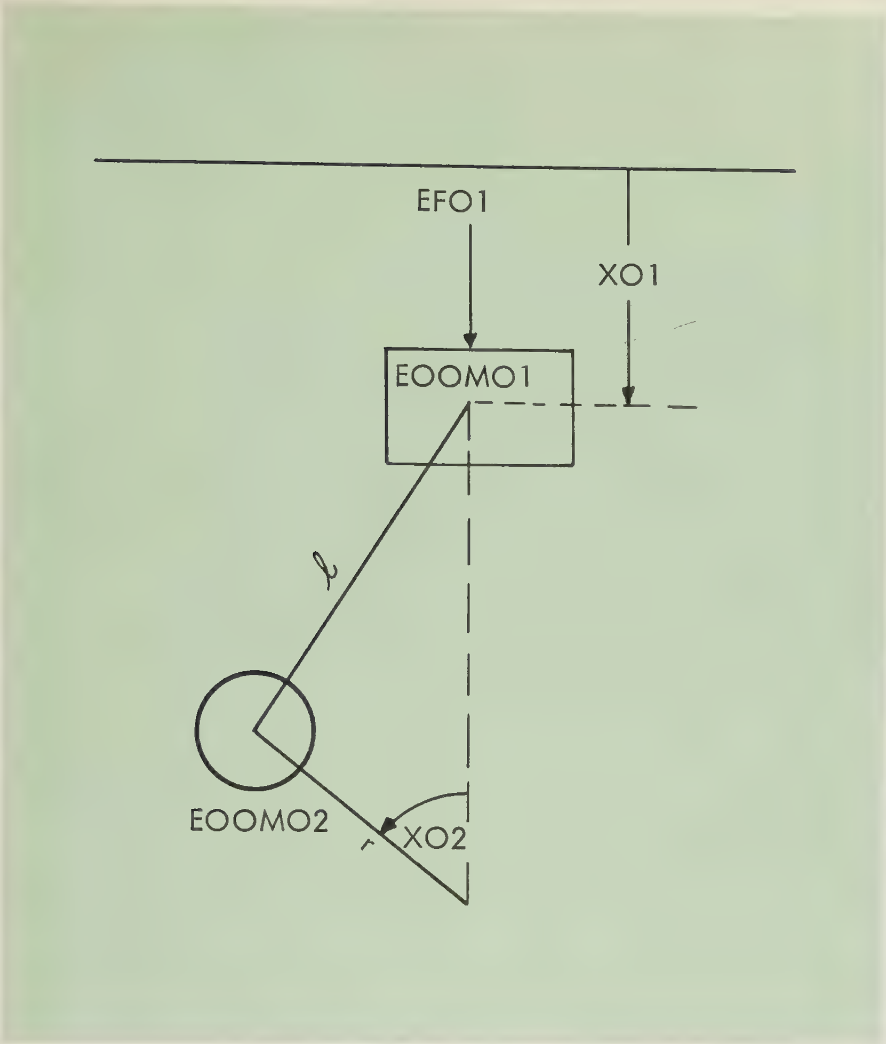


Fig. 4—A second example of a dynamics problem involving constraints is found in a study of a simple, single cylinder engine, as represented by this schematic diagram. The problem solution is the motion of the engine components when the force *EF01* is applied to the system. The DYANA notations are shown for the mass element *E00M01*, inertial element *E00M02*, and force acting upon the piston head *EF01*.

The mass-spring-damper system shown in this problem (Fig. 3a) is described in the DYANA language as follows:

X SYSTEM DESCRIPTION
E00K03, E00C03, E00K04, E00C04, E00M01, E00M02, EF01, EF02

X CONSTRAINTS
X03 = ((*X01* − *X3*)**2 + (*X02* − *Y3*)**2)**0.5 − *R3*

X04 = ((*X01* − *X4*)**2 + (*X02* − *Y4*)**2)**0.5 − *R4*.

This program is completed by using any of the features of the original DYANA computing system.

Problem No. 2:
Single Cylinder Engine

A single cylinder engine can be shown in schematic form containing a mass element, representing the mass of a piston head and a portion of the mass of a connecting rod. An inertial element also is included representing the rotational inertia due to the connecting rod and crankshaft (Fig. 4). The symbols for the various elements in this engine schematic are:

E00M01 = mass element

E00M02 = inertial element

l = length of connecting rod

r = crank radius

X01 = displacement of the mass

X02 = angle through which the inertial element has moved

EF01 = the force acting on the piston head.

The problem solution is the response of the engine when the force is applied to the piston head.

Utilizing the cosine law, the following equation can be derived which relates the displacement *X01* to the angle *X02*.

$$X01 = l + r - r \cos X02 - \sqrt{l^2 - r^2 \sin^2 X02}$$

Replacing l by a legitimate FORTRAN variable *AL*, the single cylinder engine system is described in the DYANA language as follows:

X SYSTEM DESCRIPTION
E00M01, E00M02, EF01

X CONSTRAINTS
X01=*AL*+*R*−*R**COS*F*(*X02*)−((*AL***2) −(*R**SIN*F*(*X02*))**2)**0.5.

This program is completed by using any of the features of the original DYANA computing system.

Problem No. 3:
Double Pendulum

A double pendulum system can be shown in a schematic diagram in which two masses, m_1 and m_2, are suspended on weightless, frictionless rods (Fig. 5a). Each mass has two degrees of freedom—horizontal and vertical displacement. The problem solution is the motion of the masses after they receive an initial displacement and are released.

The DYANA notation assigned to the system is the following:

X01 = horizontal displacement of m_1

E00M01 = mass of m_1 acting in the *X01* direction

X02 = vertical displacement of m_1

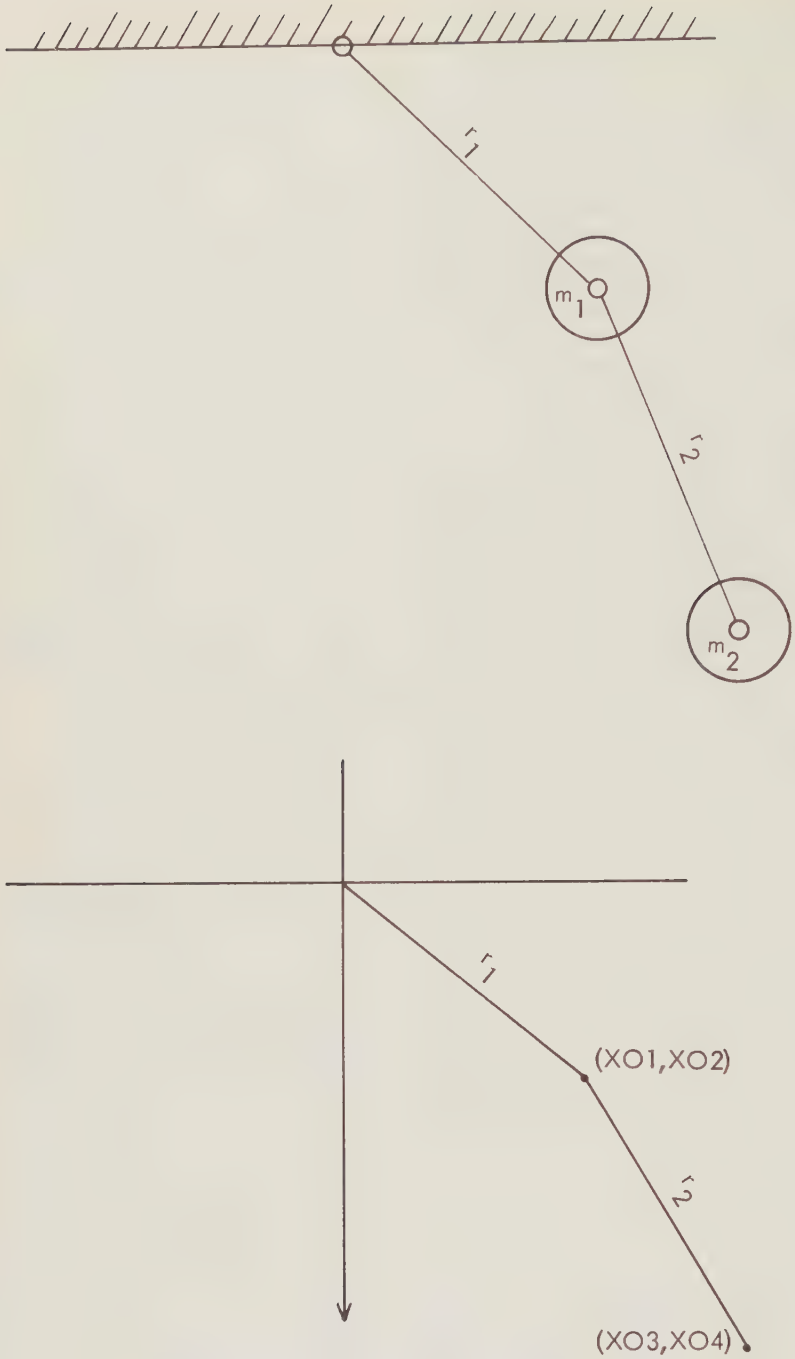


Fig. 5—A third dynamics problem is to determine the motion of a double pendulum system, as shown by the schematic diagram in (a). The two masses m_1 and m_2 are suspended on weightless, frictionless rods. Each mass has two degrees of freedom: horizontal and vertical displacement. The motions of the system can be visualized in a coordinate system (b) where *X01* and *X02* are the position coordinates of m_1 and *X03* and *X04* are the position coordinates of m_2.

E00M02 = mass of m_1 acting in the *X02* direction

X03 = horizontal displacement of m_2

E00M03 = mass of m_2 acting in the *X03* direction

X04 = vertical displacement of m_2

E00M04 = mass of m_2 acting in the *X04* direction

EF02 = force due to gravity acting on m_1

EF04 = force due to gravity acting on m_2.

With respect to the problem coordinate system (Fig. 5b), *X01* and *X02* are the position coordinates of m_1 and *X03* and *X04* are the position coordinates of m_2. Since m_1 must move on a circle about the origin and m_2 must move on a circle about m_1, the constraints associated with the system are as follows:

$$(X01)^2 + (X02)^2 = r_1^2$$

$$(X03 - X01)^2 + (X04 - X02)^2 = r_2^2$$

The double pendulum problem is described in the DYANA language as follows:

```
X SYSTEM DESCRIPTION
  E00M01, E00M02, E00M03, E00M04,
  EF02, EF04

X CONSTRAINTS
  X01**2+X02**2=R1**2
  (X03-X01)**2+(X04-X02)**2=R2**2.
```

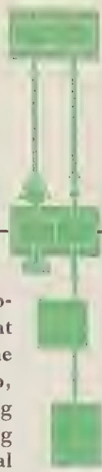
This program is completed by using any of the features in the original DYANA computing system.

Conclusion

By allowing holonomic constraints to be used in describing dynamic systems in the DYANA language, the extended DYANA computing system will provide a means for solving a larger and more complex class of dynamics problems. In keeping with the principles of the original DYANA computing system, the majority of the analysis and the digital computer programming still will be done by the DYANA system. The additional analytical work associated with constrained dynamics systems consists primarily of analytic differentiation of FORTRAN expressions. The analytic differentiator written for the extended DYANA computing system is one of the first routines of this type to do useful work in the solution of an important class of problems.

The inclusion of holonomic constraints in the DYANA computing system, while maintaining simplified usage, represents another step in the direction of automatic solution of problems on a digital computer.

A Problem in Developing Special Purpose Machines: Reducing the Drive Power Requirements



By ROBERT E. FARRAR
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Manufacturing Staff

Solving the problem reduced the drive motor size from 125 hp to 75 hp

Uncommon design problems are the expected thing for engineers engaged in the development of special purpose machines. An example of such a problem occurred in a recent project at Manufacturing Development concerned with the design and building of a machine for testing automotive driveshafts and universal joints. Principal components were two, one-to-one ratio gear boxes with 12-in. pitch diameter gears operating at speeds ranging from 400 to 6,500 rpm. This relatively high speed range for large gears, and the resulting power losses, contributed to the uncommon problem for the designer. Data on commercial gear boxes for these conditions were unavailable. And, it was felt that estimating the power losses by conventional methods would be unreliable. Thus, a study of the problem was made, which included consulting with other GM engineers having experience in related areas. The results of the study and running tests showed that the drive power requirements were excessive and possibly could prevent operation at the required speed range under certain conditions of lubricant foaming. The study also showed that by appropriate modifications to the commercial gear box and by proper control of the lubricant, drive losses could be kept to a minimum.

DESIGNING a piece of equipment whose requirements are out of the realm of everyday engineering practice requires a thorough analysis of all factors involved. An example from the recent work of Manufacturing Development, GM Manufacturing Staff, was the design of a special purpose machine. This machine involved the use of relatively large gear boxes and bearings which were to operate at speeds approximately double those ordinarily used for gear boxes of their size.

The design problems of interest in this paper are (a) the determination of drive power losses and possible ways to minimize such losses for better efficiency and economy, and (b) finding ways to eliminate lubricant foaming which would prevent operation at required speeds.

The purpose of the machine is to test automotive driveshafts and universal joint assemblies to evaluate their wear characteristics. The machine is for laboratory use in a GM Division. A test is run by installing two identical driveshafts in the machine and operating the shafts at various speeds, loads, and conditions of angular offset as set by the following design specifications:

- 0 to 500 lb-ft of torque at speeds from 400 to 6,500 rpm (low torque, high speed)
- 0 to 3,000 lb-ft of torque at speeds from 400 to 900 rpm (high torque, low speed)
- 0° to 15° angular offset of the universal joints
- Automatic stopping of the machine in case of a torque drop-off due to a component failure.

The machine consists of an arrangement of two, one-to-one ratio gear boxes facing each other between which are mounted the two driveshafts being tested. One of these gear boxes is on an adjustable base to accommodate the requirements of offset mounting and different shaft lengths. The other box is on a large bed plate which also supports the drive components and accessories (Fig. 1). The drive motor is a variable speed, d-c motor supplied by a separate motor-generator set. Because variable speed motors in the size range used are commercially available only in speeds up to 2,200 rpm, a third, smaller gear box to step up the speed is used. This is a two-speed, manual shift box with one-to-one and one-to-three ratios. It is mounted on the bed plate and connected between the drive motor and the stationary one-to-one gear box.

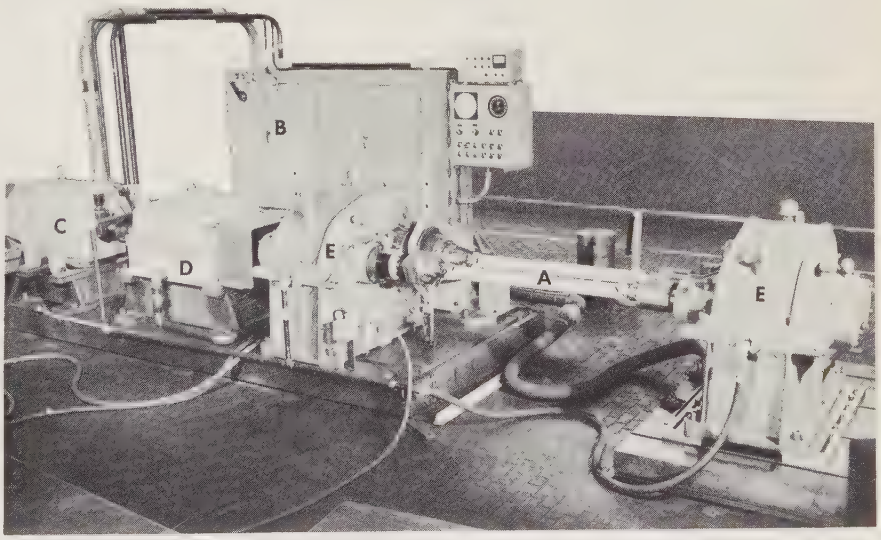


Fig. 1—The principal components of the special machine are shown in this overall view, with safety protection removed, in the Manufacturing Development shop. The machine was designed for use in a GM Division engineering laboratory in connection with developmental work on automotive driveshafts and universal joints. Two driveshafts *A* are installed for testing as shown. Machine components are: motor-generator set and controls *B*, variable speed d-c drive motor *C*, 2-speed gear box *D*, and one-to-one ratio gear boxes *E*. More information about the operation of the machine is given in the *Appendix* to this paper.

Torque, or load, is applied to the test shafts by twisting one shaft against the other. The torque loop is closed by a clutch. Torque is applied before the shafts are rotated.

The two, one-to-one gear boxes contain two, 12-in. diameter gears with a face width of approximately 14 in. These gears are herringbone type with the center portions relieved. The gear journals are supported on babbitt bearings. Two journal sizes are used in each box: 4-in. diameter and 3¼-in. diameter. Lubricating oil for the gear boxes is pumped from a central supply tank. The gears are lubricated by an oil stream directed onto one gear. The journals are pressure fed with oil at 10 lb per sq in. Excessive heat in the oil is removed by means of a heat exchanger located on the bed plate.

The Principal Losses: Bearings, Lubrication, and Windage

The problem of determining the power losses in the machine existed because of the large gear boxes with gears running at speeds up to 6,500 rpm and 20,000 ft per min pitch line velocity. Normally, industrial gear boxes are driven by electric motors which usually operate at a maximum speed of 3,600 rpm. Thus, data on drive power, bearing, and lubrication requirements were not available for the higher speeds specified. The machine was tested at the various speeds and torque requirements to identify and study the power losses, particularly at the unusual operating conditions that were involved. The results showed that above 3,600 rpm the required drive horsepower increased substantially (Fig. 2). The results also showed that under certain conditions of operation, the lubricating oil in the large gear boxes foamed and bubbled out of the air vents. This foaming condition caused the machine to slow down rapidly, which indicated the absorption of a considerable amount of the available power.

In analyzing how to reduce the power losses, it was felt that the most practical approach was to concentrate on the bearings, lubrication, and windage in the large, one-to-one ratio gear boxes. A way to eliminate the foaming also had to be found.

Manufacturing Development engineers obtained assistance on the problem of bearing losses from their colleagues at the GM Research Laboratories' Mechanical Development Department. For example, previous studies by the Research Laboratories have shown that the mechanical power loss of a journal bearing is a function of the frictional force and peripheral speed of the journal (Fig. 3). This relationship is CFS where F is the frictional force, S is the journal speed, and C is a horsepower constant. This relationship indicates that the only possible way to reduce the power consumption of the bearings for this particular machine application is to reduce the friction force, since the horsepower constant and the speed requirement cannot be changed.

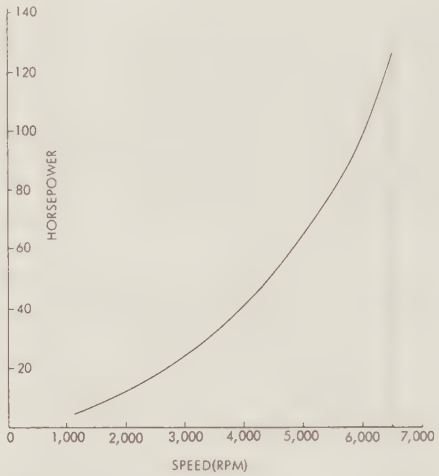


Fig. 2—During a tryout of the machine, the substantial rise in required drive horsepower at higher speeds (above 3,600 rpm) was shown by the data in this curve. The top speed requirement is 6,500 rpm.

In a properly designed journal bearing there is an oil film between the journal and bearing when the journal is turning. This oil film must support the load without rupturing and without allowing a metal-to-metal contact. The shearing of this oil film constitutes the friction force in the bearing.

Several factors affect the friction force. Among them are: oil film height, shear area of the oil film, oil viscosity, journal speed, and load carried by the bearing. Of these factors only the shear area of the oil film and oil viscosity could be altered to reduce friction force in the bearings of the gear boxes. (Increasing the oil film height was not recommended because this would require a larger bearing clearance which, in turn, might adversely affect both the running clearances and the backlash of the gears.)

Shear Area

Before deciding to reduce the shear area of the oil film, engineers had to be assured that the load carrying ability of the bearings would not be impaired for this application. The low-speed operation of the machine is the governing condition since the load capacity of a journal bearing increases with journal speed (oil viscosity remaining constant). Furthermore, under the operating specifications of this machine, the high torque condition exists at the low speeds and, conversely, the low torque exists at the high speeds. During the analysis of this load problem, a test of the machine showed that the amount of torque locked into the driveshafts at the higher speeds had very little effect on the drive power required (Fig.4).

Bearing load calculations for the low-speed condition were made which showed that the bearing areas could be safely reduced by about 20 per cent. This reduction in bearing area reduced the oil film shear areas to achieve the objective of cutting the friction force, and, therefore, the power required. For the complete machine, the maximum saving achieved by this means was 13 hp.

Oil Viscosity

Oil viscosity affects the frictional force of a journal because of the viscous drag produced by the oil. Viscosity is a measure of the resistance of a fluid to flow due to its fluid friction. Viscosity is the very property of an oil that makes possible the operation of a journal bearing. At the

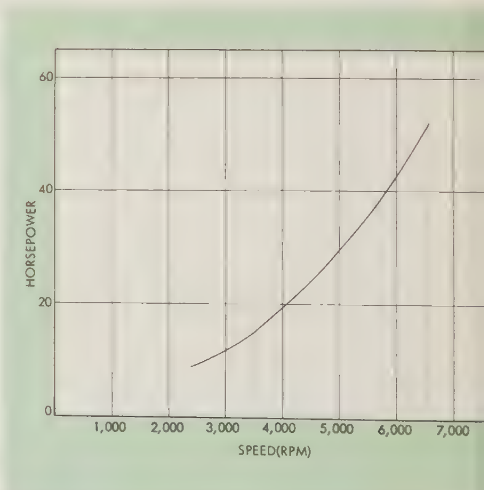


Fig. 3—A study of the power losses in the journal bearings of the large gear boxes showed these data on variation with increased speed of the journals. The loss shown is for a single gear box.

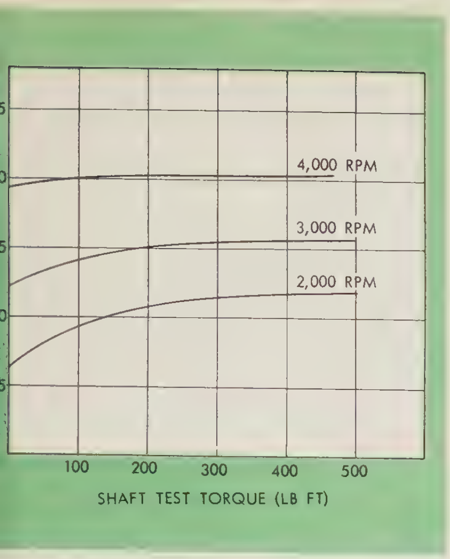


Fig. 4—Information was sought on how the power requirements might be affected by the amount of torque locked into the test shafts. These curves show values of torque locked into the test shafts plotted against the required drive power. It can be seen that as speed increases, its effect becomes less.

proper viscosity, oil is drawn into the bearing by the rotation of the shaft faster than it is squeezed out of the bearing. This action supports the rotating shaft.

When the temperature of oil goes up, its viscosity and, consequently, the viscous drag, goes down. Therefore, the selection of the proper operating temperature and oil viscosity for the gear box bearings—particularly at the high speeds—was the next logical step in looking for ways to reduce losses in the bearings. In the first tests during tryout of the machine, the oil temperature at the high running speeds was held at 175°F at the oil cooler. By changing the control of the heat exchanger, this oil temperature was allowed to rise to 225°F. The result was an overall saving in drive power of an additional 12 hp.

In further testing of the machine, however, it was felt that even with the temperature increase, the oil viscosity still was higher than necessary for the high speed conditions. After further work, the oil was changed from No. 30 AGMA gear compound to No. 10 AGMA operating at a temperature of 225°F. This change to an oil of lower viscosity dropped the power required at the peak speed condition by another 14 hp.

It is important to note that these revisions in the oil viscosity and temperature were applied only to the high speed, low torque operating condition of the testing machine where the need for horsepower savings was the greatest and where bearing load carrying capacity was many times the capacity required. A higher viscosity oil at a lower temperature was specified for the low speed, high torque operating condition where the bearing loads are heavier.

Windage and Foaming

After making the changes in bearings and in lubrication conditions, the total drive horsepower was reduced by 39 hp. The remaining principal problems that appeared to affect the power requirements were windage and foaming.

Windage losses at high speeds are caused by the gear teeth fanning or pumping air, oil and/or air-oil mixtures existing inside the gear box. Losses due to the resistance of the air itself are unavoidable unless the gears are operated in a vacuum. Any oil vapor, mist or foam entrained with the air will cause increased losses due to the increased density of these mixtures. Lubricating and cooling oil thrown from a rotating gear or shaft directly into the teeth of another gear or, deflected by the housing into a gear, will increase windage losses. Air currents generated inside the gear box by the gears may be so intense as to partially block oil drain passages thereby raising the oil sump level until the gears dip into solid oil. Air currents may blow solid oil up the housing walls until the oil falls back down into the gear teeth. Foam generated by such beating of the oil may also partially block oil drain passages. Such contact with solid oil and air-oil mixtures creates a significant resistance to the gear rotation at high speed and absorbs a large amount of power. Such contact, however, can be minimized by proper design.

In connection with these problems, Manufacturing Development engineers consulted with engineers at Allison Division who had previous experience with foaming and windage losses in high speed gears. Some of the Allison applications involved large gears running at pitch line velocities even higher than those in this shaft testing machine. In one extreme case, the required drive power was reduced an estimated 90 per cent by eliminating foaming and reducing the windage losses. The method used was to install shrouds around the gears to control the throw-off oil and the air currents within the gear box so as to provide smooth flow patterns for both. Applying this information, shrouds and exit openings were built into the gear boxes of the shaft testing machine (Fig. 5). Further tests then showed that foaming was eliminated and the saving in power loss from windage at the top speed of 6,500 rpm amounted to 16 hp.

The 16-hp saving in windage loss added to the savings of 39 hp found in the bearings and lubrication produced a total of 55 hp (Fig. 6).

Conclusion

Testing confirmed that about 90 per cent of the power losses in this machine were related to the bearings, gears, and lubrication in the large gear boxes. By applying the design changes described, the required drive horsepower was reduced from 125 hp, as indicated in the first machine tryout (Fig. 2), to 70 hp (Curve *E*, Fig. 6). A 75-hp electric motor, therefore, was used.

The development of this special machine presented an example of the kinds of unusual problems which often occur in such work. In this case, the problem was the large gear boxes running at unusually high speed and the lack of commercially available data at this condition. The machine tryout made it clear that conventional methods for estimating power losses were not reliable when the speed of the gears rose to 6,500 rpm—approximately twice the usual speed of the industrial electric motor. For example, at usual industrial gear box speeds, power loss is estimated by allowing a percentage of torque loss for each transfer through a gear set plus an additional reserve for a factor of safety. Typical calculations, as applied to the gear boxes of this machine, are as follows:

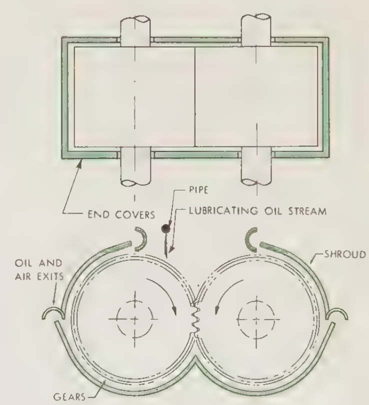


Fig. 5—To reduce the windage losses and eliminate foaming of oil in the gear boxes, shrouds and exit openings were built into the gear boxes as shown in these sectional views.

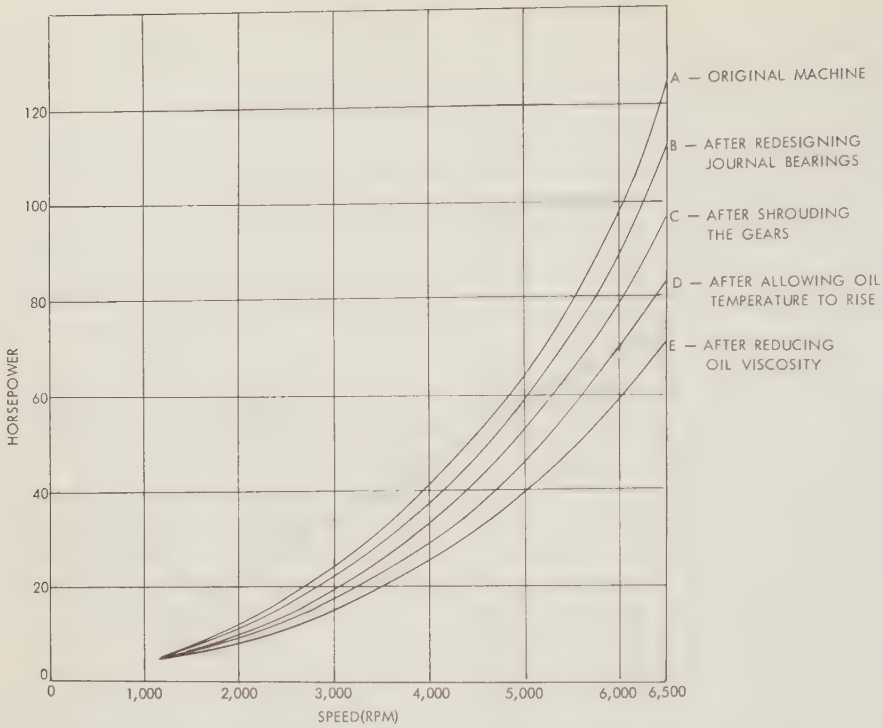


Fig. 6—These curves summarize the results of the various steps taken to reduce power losses in the gear boxes of the test machine. The top curve *A* shows the power consumption of the machine when the first tryout was made. The bottom curve *E* shows the power consumption after the total savings of approximately 55 hp were made. The dashed line represents the power available from the 75-hp electric motor through the one-to-three ratio gear box.

Large Gear Boxes

Locked-in test torque = 500 lb-ft

Running torque per transfer = 2 per cent

(The manufacturer estimates 1½ to 2 per cent for precision ground gears of low ratio.)

Number of transfers = 2

Running torque loss

$$= 500 \left(\frac{2}{100}\right) (2) = 20 \text{ lb-ft}$$

Allowance for bearings and other losses (100 per cent) = 20 lb-ft

Total calculated torque required to drive the two large gear boxes = 40 lb-ft.

Small Gear Boxes

Torque output required = 40 lb-ft

Number of transfers = 2

Running torque loss

$$= 40 \left(\frac{2}{100}\right) (2) = 1.6 \text{ lb-ft}$$

Allowance for bearings and other losses (100 per cent) = 1.6 lb-ft

Total torque loss in small gear box (considered at the output speed for ease of calculation) = 3.2 lb-ft.

Both Gear Boxes

Total torque loss (considered at the high speed condition) = 43.2 lb-ft.

This represents a total calculated power loss of approximately 15 hp at 1,800 rpm and approximately 30 hp at 3,600 rpm. Readings of actual power losses from tests of the machine were reasonably close to these estimates at the indicated speeds.

This project also was, of course, a confirmation of the advisability of making thorough studies of all design situations, both usual and unusual. The help of other GM engineers with experience in the various areas involved greatly aided the final answer to the question of how to reduce the power losses.

Bibliography

Related literature in this field includes the following:

Norton, A. E., *Lubrication* (New York: McGraw-Hill Book Company, Inc., 1942).

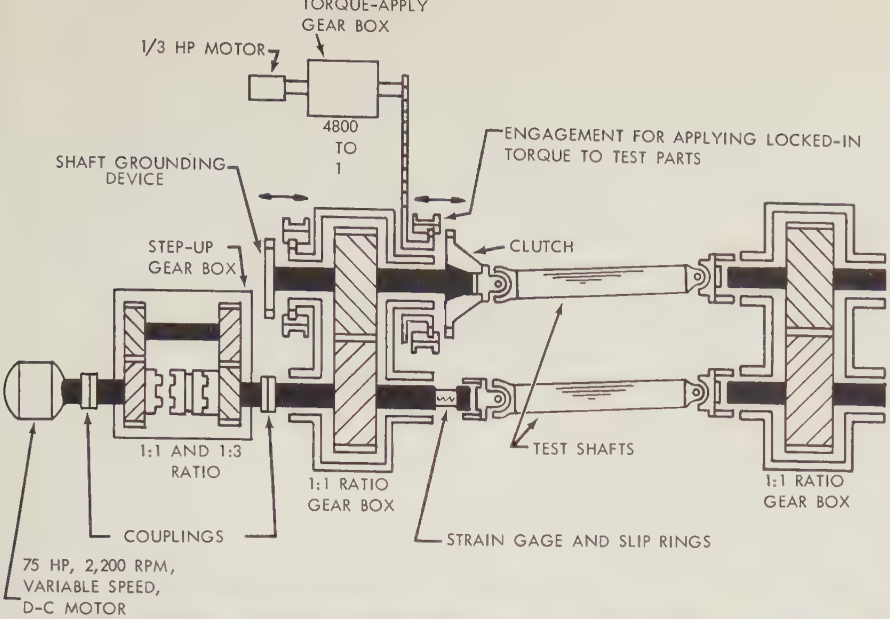
Wilcock, D. F., and Booser, E. R., *Bearing Design and Lubrication* (New York: McGraw-Hill Book Company, Inc., 1957).

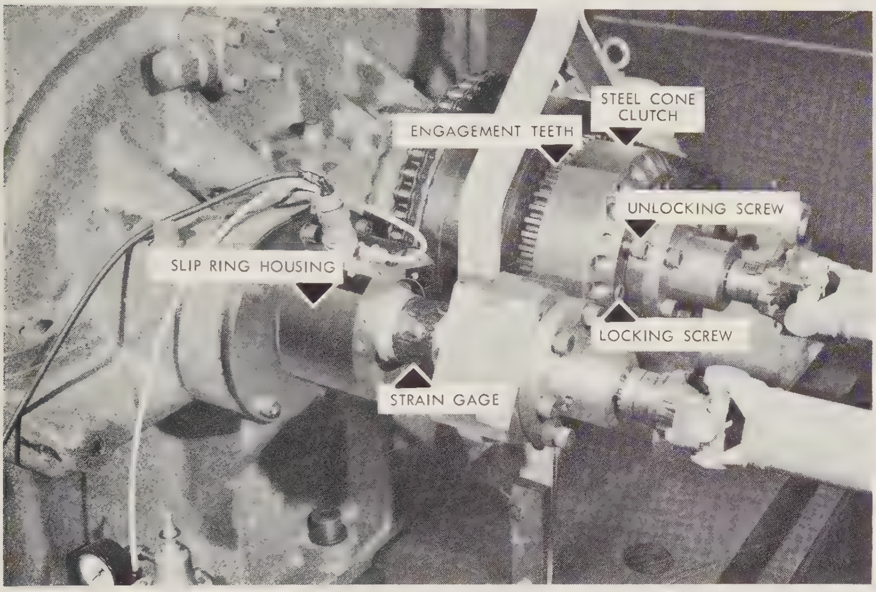
APPENDIX

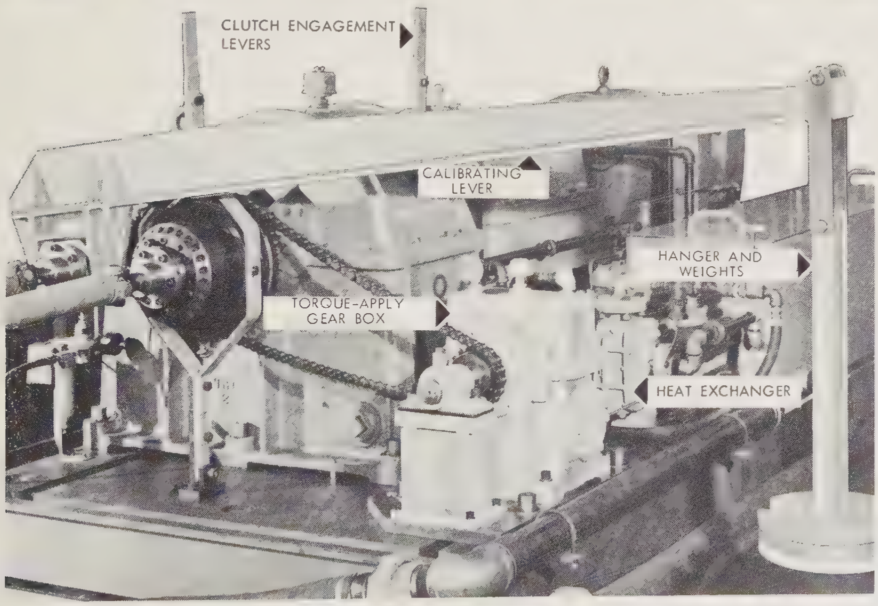
This appendix presents additional information about the components and operation of the special machine described in the preceding paper. Please refer to the accompanying Figs. 1A, 2A, and 3A, which illustrate most of the parts described here.

The machine is used during developmental work to study the wear characteristics of experimental automotive driveshafts and universal joints while running at various conditions of speed, load, and angular offset. As explained in the text of the paper, the driveshafts are tested at low speeds with high torque and at high speeds with low torque. When operating in the high speed, low torque range, the torque loop represents a transfer of 620 hp maximum. In the low speed, high torque range, the loop represents a transfer of 515 hp maximum.

The machine consists of a bed plate for mounting the driving and control components; a 75-hp, 2,200-rpm, variable speed d-c motor with a motor-generator set to supply d-c current to the drive motor; a two-speed gear box having one-to-one and one-to-three ratios to provide the wide range of speeds and torque; two, larger gear boxes having one-to-one ratios; a means to apply locked-in load torque to the test shafts; a means to constantly monitor the







locked-in torque; coupling and adapters to install shafts of different sizes; and a means of calibrating the torque measuring equipment.

To conduct a test, two identical driveshafts are installed between the large gear boxes as shown. The gear box at the right can be moved to accommodate shafts of different lengths and to provide the required angular offset. Test torque is applied by twisting one shaft against the other. The torque loop is closed by a specially designed steel cone clutch. The clutch is mechanically operated by means of locking and unlocking screws.

To apply the test torque to the test shafts, a 4,800-to-one ratio gear box, driven by a 1,200-rpm, 1/3-hp motor, is connected through a chain drive to the clutch engagement ring. Torque is applied to the test shafts, before the machine is started. A shaft grounding device, installed on the large gear box, prevents rotation of the shafts while the torque is being applied.

Test torque values are indicated by instrumentation using a strain gage, slip rings, bridge circuit, and voltmeter. The strain gage is mounted in one leg of the torque loop. The voltmeter converts readings to lb-ft. Since the strain gage must be calibrated periodically, a dead weight system is provided. This consists of a 7-ft lever placed over wrench flats on the same journal which has the strain gage. A hanger and known weights are placed on the end of the lever for calibrating.

A shut-off device to stop the machine in case of shaft failure is included in the strain gage instrumentation. It is set at a pre-determined percentage of the total torque being applied to the shafts.

Since torque is applied to the shafts while the machine is stopped, the machine starts under a condition of full static load. This requires 100-per cent to 200-per cent excess motor torque over the value for running. To satisfy this condition, the motor control is equipped with a time delay overload so that the motor draws excess current for a few seconds during starting.

In the low speed range for testing (400 rpm to 900 rpm), the two-speed gear box is operated in the one-to-one position and the drive motor speed is varied as required. In the high speed range (400 rpm to 6,500 rpm), the one-to-three ratio of the gear box is used.

The Organization of Research and Engineering Activities at Delco Radio Division

By JAMES H. GUYTON and
DR. FRANK E. JAUMOT, JR.
Delco Radio Division

Where complex products require reliable performance

Fig. 1—This artist's sketch shows Delco Radio's new engineering and research building now under construction in Kokomo, Indiana. When completed, it will contain more than 125,000 sq ft of floor space for offices and laboratories of the Semiconductor Research and Engineering Department and the Radio Engineering Department.

For a manufacturer to produce the type and quality of products needed today, increased emphasis must be placed on creative research and sound engineering. At Delco Radio Division, the Semiconductor Research and Engineering Department and the Radio Engineering Department are organized to coordinate the research and engineering activities needed to manufacture reliable electronic products. The Semiconductor Research and Engineering Department is responsible for solid state physics research, development of solid state military and commercial products, and development of components for general electronic applications. The Radio Engineering Department is responsible for designing, developing, and testing the commercial electronic products manufactured by Delco Radio. These responsibilities require work ranging from investigating the discoveries of applied science to testing materials, components, and finished products. The work of these two Departments has provided such electronic products as the signal seeking car radio, an all-transistor car radio, a highway communications system (Hy-Com), and a full line of power transistors.

THE increasing complexity of almost all manufactured goods has recently made it more difficult for industry to produce the dependable and reliable products needed by customers. To overcome this problem, manufacturers are placing greater emphasis on creative research and sound engineering.

This emphasis is especially true in the electronics industry which is faced not only with complex commercial products, but also with the responsibility for developing and producing intricate electronic equipment to meet the exacting performance specifications required by military missiles and space exploration devices.

Delco Radio Division, a long-time producer of automobile radios, has demonstrated in recent years its capabilities in other commercial and military electronic and semiconductor areas, including the production of power supplies for the guidance systems of military missiles.

Under the decentralized operations of General Motors, Delco Radio is responsible not only for research, development, design, and manufacture of final electronic products, but for their principal components as well. For example, Delco Radio produces components such as power transistors, rectifiers, transformers, coils, powdered iron cores, ferrites, printed circuits, zinc and aluminum die castings, plastic molded parts, punch press and screw machine parts, and gearing, plating and precision tuning mechanisms. The diversity of its products requires a wide range of research and engineering activities which must be directed and coordinated effectively in order to supply reliable products.

The Semiconductor Research and Engineering Department and the Radio Engineering Department are responsible for the research and engineering activities of Delco Radio (Fig. 1). Coordination between these Departments is achieved primarily through an informal type of liaison. If a problem arises, for example, staff engineers from the two Departments meet informally to discuss a solution.

More formal coordination, however, is made possible through two management level committees: an Engineering Committee and a New Products Committee, both under the chairmanship of the Division's general manager. Other members include the director of the Semiconductor Research and Engineering Department, the chief engineer—radio, and representatives from the other staff level Departments.

Additional liaison between the two Departments is achieved by a staff engi-

neer in the Semiconductor Research and Engineering Department whose principal duty is to maintain close contact with the Radio Engineering Department.

Need for Special Power Transistors Led Delco Radio Into Semiconductor Field

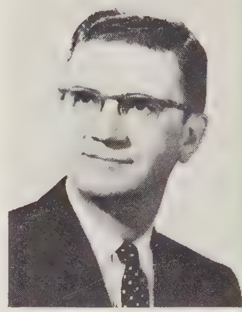
The Semiconductor Research and Engineering Department is, broadly speaking, responsible for the development and evaluation of any semiconductor device which may be required by Delco Radio.

The Division became interested in a semiconductor program in 1954, when it could not find a manufacturer willing to supply a transistor meeting the required specifications and cost. A semiconductor laboratory was established that year and later Delco Radio began manufacturing transistors.

The first large scale application of power transistors, which offer greater ruggedness, higher reliability, higher speed, smaller size, and require less power to operate than the vacuum tubes they replace, was in the push button radios built for 1957 Pontiac and Chevrolet cars. All Delco Radio car radios used the power transistor in 1959 and 1960. Today, the Division offers a complete line of power transistors and also is producing silicon rectifiers.

The work of the Semiconductor Research and Engineering Department is divided into three areas: Semiconductor Device Research and Development, Semiconductor Applications and Evaluation, and Semiconductor Military Projects (Fig. 2). Each area is headed by a manager.

Some Comments on the Operations of Delco Radio Division



UNDER the decentralized organization of General Motors, the general manager of each operating Division is responsible for building his own organization, coordinating its efforts, and planning its progress. Subject to certain broad policy controls and to a few activities which are necessarily centralized, each Division operates largely as an independent business.

This means, of course, that practically every Division is an integrated facility for the research, development, design, and manufacture of its products. Delco Radio Division, one of the GM Divisions producing accessory parts for motor vehicles, manufactures automobile radios, power transistors, silicon rectifiers, heater and air conditioning controls, and static machine controls for commercial markets, along with power supplies for the guidance systems of some of our nation's latest military missiles.

Delco Radio's production facilities—two plants in Kokomo, Indiana, and one plant in Chicago—include some of the most advanced assembly equipment in the electronics industry and many specialized departments designed to improve manufacturing techniques and processes.

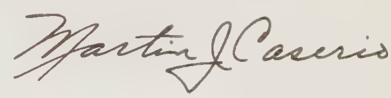
But modern production equipment and methods are not the only ingredients essential for success in the competitive atmosphere of business. In this rapidly changing technological world, each manufacturer must continually improve research and engineering techniques in order to provide customers with the type and quality of products they require.

Since its inception in 1936, Delco Radio has continually expanded and improved its management skills, research facilities, and scientific and engineering team. This expansion continues, as evidenced by a new engineering and research building now under construction in Kokomo. In addition, the services and facilities of the GM Technical Center, Proving Ground, and field test sites in Arizona, Colorado, and Florida are available when required.

Although the products of Delco Radio are primarily electronic or electrically oriented, engineers and scientists from many academic disciplines are needed in our work. Electrical, mechanical, and industrial engineers, chemists, physicists, metallurgists, and mathematicians combine their knowledge and experience at Delco Radio to translate theoretical concepts into practical, functional products.

A fundamental principle of General Motors management is to place a great emphasis on people and how they are organized within the business. This emphasis is important since the main difference between a business success or a business failure is people. Not only must these people be given a job commensurate with their training and ability, but they must be placed in an organizational framework that permits them to use their skills in the best possible manner.

The paper presented here describes the research and engineering facilities of Delco Radio and illustrates how our people contribute their specialized knowledge to provide our customers with economical and reliable products.



MARTIN J. CASERIO,
General Manager
Delco Radio Division

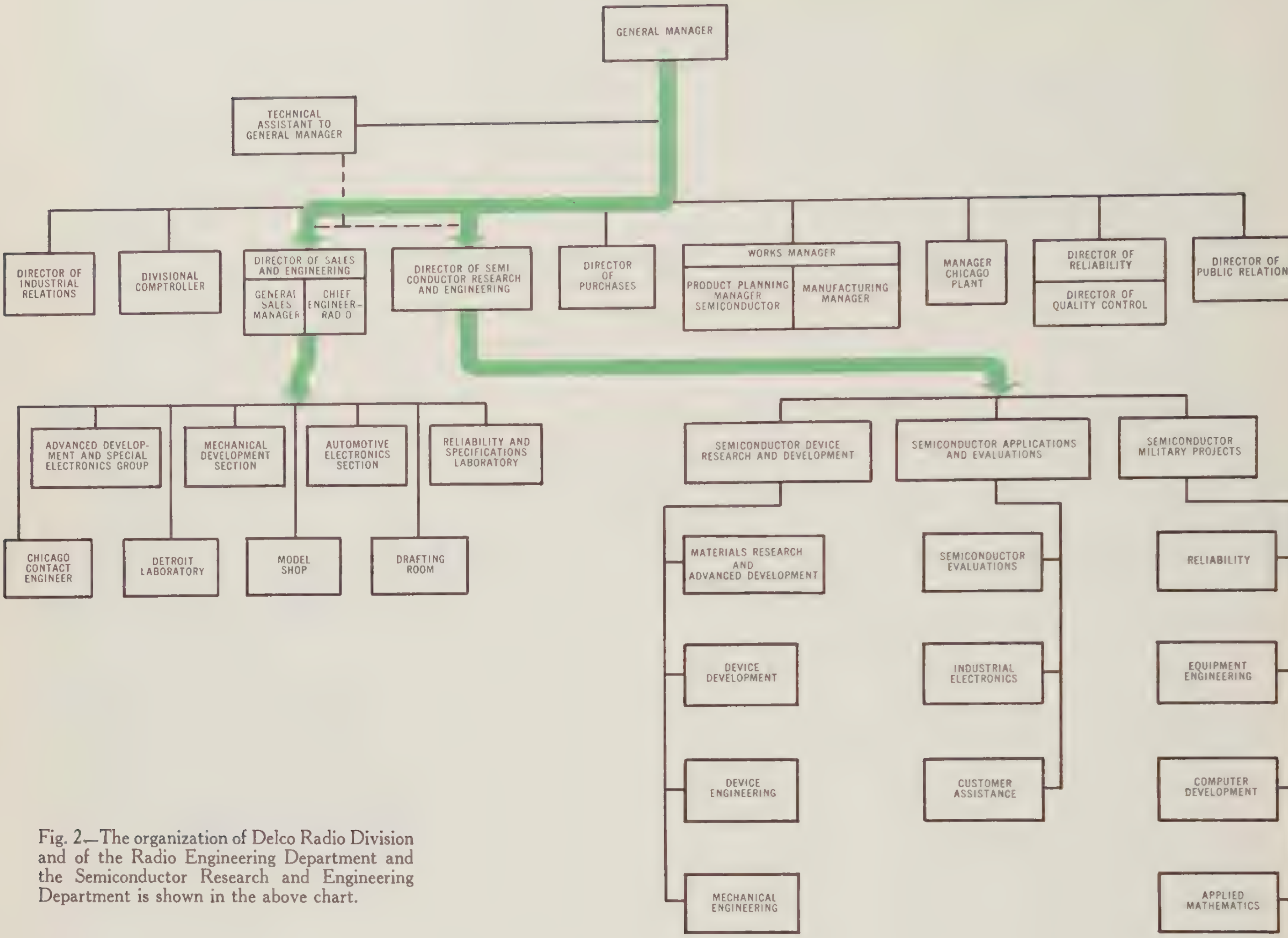


Fig. 2—The organization of Delco Radio Division and of the Radio Engineering Department and the Semiconductor Research and Engineering Department is shown in the above chart.

Semiconductor Device Research and Development

Semiconductor Device Research and Development, which is divided into four Groups, is responsible for conducting semiconductor materials research; conceiving, developing, and engineering new semiconductor devices; piloting and introducing devices into production, and assisting semiconductor production. Each of the four Groups is headed by a supervisor.

Materials Research and Advanced Development Group

The Materials Research and Advanced Development Group, as the name implies, consists of two sections. The first section, Materials Research, is responsible for developing techniques for producing semiconductor crystals and for measuring the properties and improving the quality of the crystals. This section now is studying improved methods for growing high purity silicon single crystals, investigating the quality of p-n junctions formed by various techniques, and conducting a program on the growth of semiconductor materials in the form of flat ribbons so the waste involved in present methods can be eliminated.

The second section, Advanced Development, is the place where a semiconductor device begins its development. Here the original concept of a new device or a new method for making an existing device is formulated. The responsibility of this section ends when it demonstrates that a device can be effectively fabricated and that it is capable of performing its intended function. Some of the projects this section works on are the development of silicon solar cells and tunnel diodes, the fabrication of molecular circuits, and basic studies in diffusion (Fig. 3).

Device Development Group

Semiconductor device concepts of proven feasibility are taken by the Device Development Group and reduced to practical applications. It also adapts devices to fit particular applications. This Group is presently working on two different silicon power transistors and a number of silicon rectifiers.

Device Engineering Group

The pilot fabrication of new devices to prove they can be mass produced, introduction of the device into production,

redesign of existing production devices, and general production assistance are the functions of the Device Engineering Group. This Group developed Delco Radio's new high current transistors.

Semiconductor Mechanical Engineering Group

The Semiconductor Mechanical Engineering Group operates as a support facility for the other three Groups. It designs the semiconductor device containers, fixtures, and dies used in device development and checks and processes all drawings associated with a new device. A model shop, which builds the early models of these items, also is a part of this group.

Semiconductor Applications and Evaluations

The second major area, Semiconductor Applications and Evaluations, consisting of three Groups, was formed for two reasons: first, it is important to have a detailed evaluation of new and production devices performed by a Group separate from the Groups which develop and produce the device, and second, some of the devices which are developed are so unique that applications must be found for them.

Semiconductor Evaluations Group

The Semiconductor Evaluations Group is responsible for evaluating transistors under development as well as those in production. It continually searches for new tests and test procedures, evaluates competitors' transistors, issues a weekly quality analysis report on all transistors in production, and conducts a reliability study on power transistors to be used in missile applications. The environment laboratory, operated by this Group to evaluate transistors under operating conditions (Fig. 4), also serves other Delco Radio departments.

As a result of the efforts of this Group, Delco Radio became the first commercial laboratory approved by the Armed Services Electro Standards Agency to test some transistors for military qualifications. The Division also was selected as part of the reliability program for the Minuteman missile.

Industrial Electronics Group

The development of new and improved transistor applications for industrial use is the responsibility of the Industrial Electronics Group. Its latest project was the development and assembly of a static machine control unit, a completely transistorized system designed to control sequential operations of industrial machinery with greater reliability and flexibility than can be obtained with relay controls.

Customer Assistance Group

The final Group in this area is the Customer Assistance Group which provides technical advice to Delco Radio customers by evaluating customer specifications and issuing internal test procedures, specifications, and cost requests. It also prepares data sheets and publishes application notes on special circuits, methods of testing transistors, and particular troublesome areas encountered in using semiconductor devices. This Group maintains small application laboratories in conjunction with Delco Radio sales offices in Santa Monica, California, and Newark, New Jersey.

Semiconductor Military Projects

The newest area in the Semiconductor Research and Engineering Department developed as a natural evolution from Delco Radio's background in general electronics. Since the Division had considerable experience in various applications of semiconductor devices, it formed Semiconductor Military Projects and entered into the production of high precision power supplies used in the guidance systems of ballistic missiles. Delco Radio's experience in highly reliable transistorized and miniaturized equipment also made it a logical place to conduct work in special purpose digital computer systems, which is another function of this area. Semiconductor Military Projects consists of four Groups, each headed by a supervisor.

Reliability Group

The Reliability Group, working in close cooperation with Delco Radio's director of reliability, establishes reliability programs and procedures, product specifications, report procedures and forms, and is generally responsible for the approval of all reliability phases of a semiconductor product.

Equipment Engineering Group

The design and development of static power supplies including inverters, converters, rectifiers, and regulators; the mechanical package design of all equip-

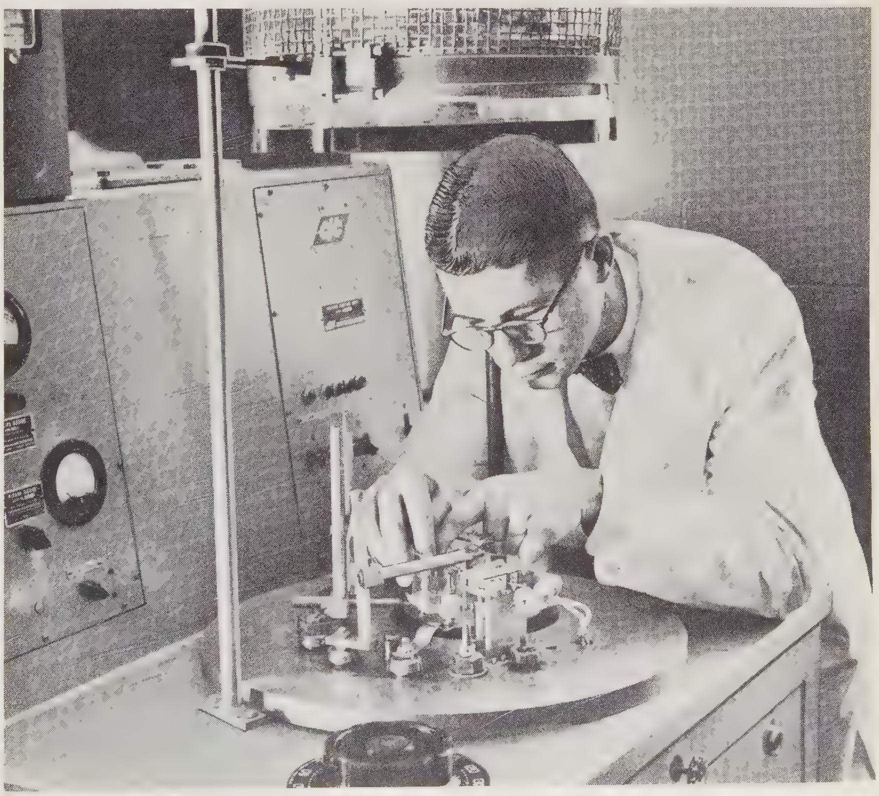


Fig. 3—This high vacuum evaporator is used in the development of thin film evaporation techniques for micro-electronics in the Advanced Development Section of the Semiconductor Research and Engineering Department.

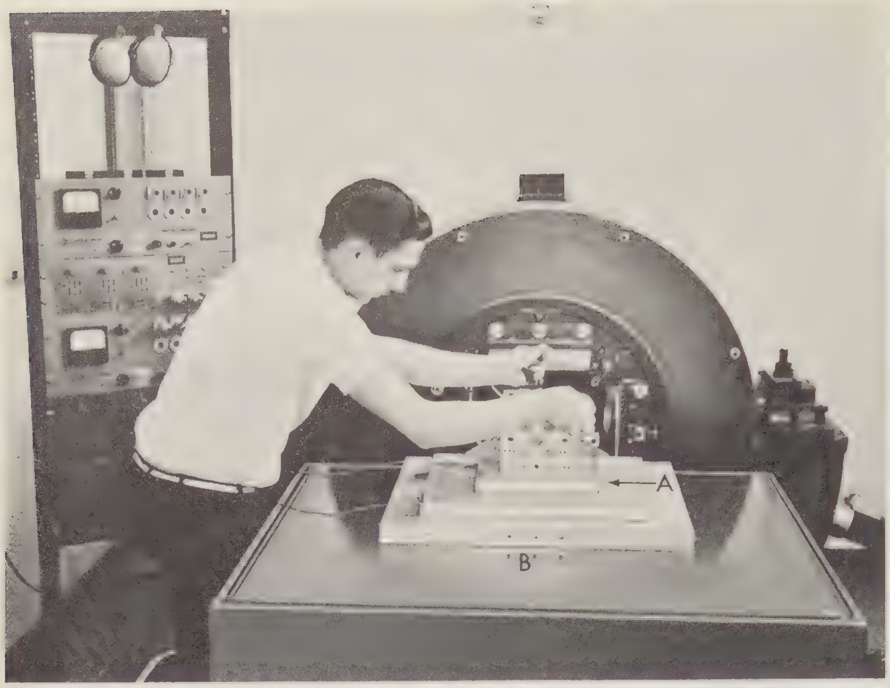


Fig. 4—In the environment laboratory, operated by Semiconductor Applications and Evaluations, a vibration machine is used to test transistors and complex missile electronics systems for their ability to withstand mechanical vibration. The equipment, located in a special soundproof room, can subject a system to a force as great as 50 *g*—many times the force it would have to withstand in a normal missile flight. The transistors shown above have been placed on a base plate *A*, which rests on an oil covered table *B*. Control equipment for the machine is located in an adjacent room.

ment developed; and the design and development of analog circuits in military applications are functions of the Equipment Engineering Group (Fig. 5). It recently delivered a series of modular circuits consisting of servo circuits, preamplifiers, and power controls to the Instrumentation Laboratory of the Massachusetts Institute of Technology for use in an advanced missile guidance system. The power supply work of this Group has resulted in the design and development of precision static power supplies for Thor, Mace, and Titan ballistic missiles.

Computer Development Group

As its name signifies, the Computer Development Group designs and develops special purpose digital computer systems for military applications. This Group recently developed a computer for the White Sands Missile Test Range in New Mexico and a data preprocessor for the GM Technical Center in Warren, Michigan. It has also developed a series of switching circuits which are now being sold commercially, either as printed circuit card modules or as three dimensional, welded wired, epoxy encapsulated modules. A magnetic core memory, a buffer storage memory, a memory exerciser computer, and a special purpose computer, designed to life test computer modules and other computer accessory equipment also have been designed and fabricated by this Group.

Applied Mathematics Group

The Applied Mathematics Group operates primarily as a service facility for the other Groups in the Semiconductor Research and Engineering Department. It works on reliability programs and analytical studies connected with computer design.

Product Design and Testing Are Important Functions of Radio Engineering Department

The Sales Department and the Radio Engineering Department, due to their interdependence, are coordinated by a director of sales and engineering who reports directly to the general manager.

The Radio Engineering Department has four specific functions:

(a) To design the electronic products manufactured by Delco Radio

(b) To test new products and their components

(c) To maintain close liaison with the engineering departments of customers

(d) To develop new products.

In a normal year, this Department designs and releases for production about 20 radio models, including manual tuning, push button tuning, signal seeking, and all-transistor models, plus 8 automobile heater and air conditioner controls, and a low frequency garage door radio control, which has been added in recent years.

The Radio Engineering Department consists of four major areas: Advanced Development and Special Electronics Group, Mechanical Development Section, Automotive Electronics Section, and a Reliability and Specifications

Fig. 5—Since military electronic equipment requires long life and reliable, troublefree performance, its circuits are carefully designed and thoroughly tested in this circuit development laboratory before being released for production.

Laboratory, each supervised by a staff engineer. In addition, four service Groups are attached to the Department (Fig. 2).

Advanced Development and Special Electronics Group

One avenue for industrial growth is through the creation of new products which, in turn, generate new markets. To continue Delco Radio's expansion in the electronics field, the Advanced Development and Special Electronics Group is responsible for developing new automotive electronic products, as well as control and electronic products for the home.

Some of the products developed by this Group are a radar proximity warning device, a highway communications system (Hy-Com), a full line of power transistors for car radios, and a transmitter and receiver system for garage door remote controls.

Mechanical Development Section

The two main responsibilities of the Mechanical Development Section are first, to design the annual production models, and second, to help with the development of new products, particularly from a mechanical aspect.

To accomplish its first responsibility, this Section:

- Maintains liaison with customers
- Directs draftsmen in the preparation of drawings, parts lists, and mechanical specifications
- Works with the Model Shop to produce product samples
- Coordinates cost information, tooling requirements, and manufacturing procedures with the production departments, and
- Cooperates with the Automotive Electronics Section in developing new product design.

This last effort is accomplished through a project team approach in which a mechanical engineer from the Mechanical Development Section and an electrical engineer from the Automotive Electronics Section work together on a particular project, usually for a specific customer (Fig. 6).

To fulfill its second responsibility, the Section is organized into developmental sub-groups composed of mechanical development engineers. Emphasis is placed on creativity and flexibility of project assignments in these sub-groups. The projects range from short studies of feasibility of a new product to an entire departmental effort, such as the electronic heater and air conditioning system project, which required several years to complete.

Automotive Electronics Section

The responsibility for the electronic design of the products manufactured by Delco Radio rests with the Automotive Electronics Section.

This responsibility begins with the generating of ideas concerning the electronic design of new products. After these ideas are investigated for practicality, samples of the most feasible ones are developed for customer evaluation. In this phase, electrical engineers of the Section work with mechanical engineers from the Mechanical Development Section. When an idea is finally accepted by a customer, as the result of a joint effort by the Radio Engineering Department and the Sales Department, the Section helps prepare the design for production. A continuing function, of course, is to improve the electronic reliability of current production models.

A well equipped acoustics laboratory, in which advanced development and production design of loudspeakers and loudspeaker baffle systems are conducted, is included in the Section. Typical laboratory studies include tone compensation in radio receivers to produce the desired over-all tone in new car radio models. Also, the laboratory has been used for research in the use of digital computers for analysis and design of loudspeaker cones and acoustic load characteristics presented to the loudspeaker by the contour of the automobile interior.

Reliability and Specifications Laboratory

Since any product is only as good as the dependability of its components, Delco Radio conducts an extensive program of reliability and quality control. An important segment of this program centers in the Reliability and Specifications Laboratory where electrical engineers, chemists, and metallurgists, working with the other design and development Sections, continually test and evaluate the materials, components, and finished products used and produced by Delco Radio.

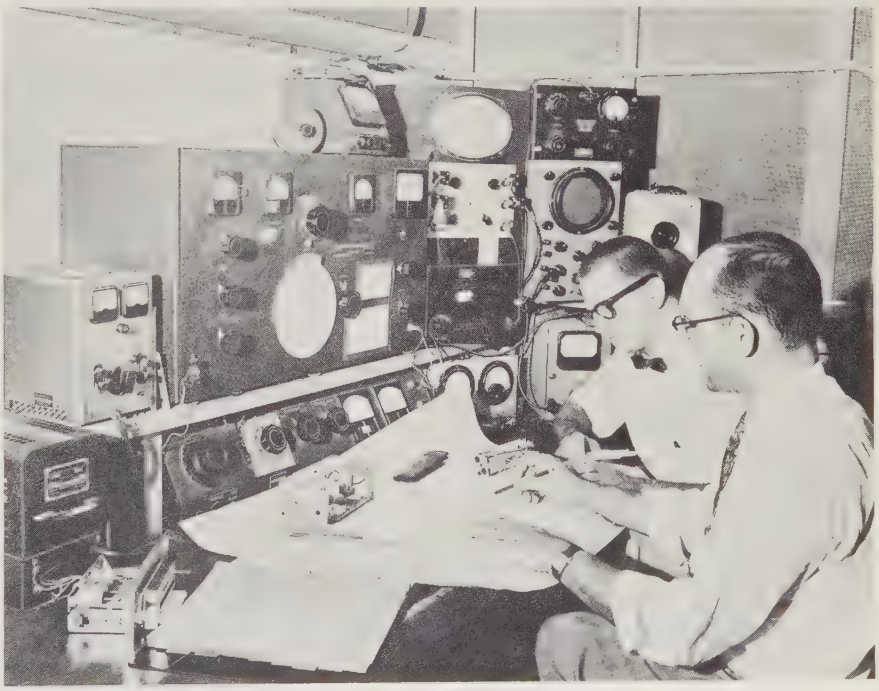


Fig. 6—Developing a new design for a car radio involves cooperation between many engineers. Here an electrical engineer from the Automotive Electronics Section and a mechanical engineer from the Mechanical Development Section discuss a radio design problem. After a sample set is built, it is tested with the equipment shown here to determine how it will operate in a car. The equipment is located in a room surrounded by double copper screens which keep out interference from radio stations and static during the tests.

Fig. 7—In eight hours, this bench setup in the Reliability and Specifications Laboratory automatically operates radio tuner assemblies for an equivalent of 10 years in use. The number of failures and their causes are analyzed and reported to the appropriate departments. The Laboratory regularly tests such components as transistors, condensers, printed circuit boards, and volume controls, as well as complete radio sets, for operation at high and low temperatures and under extreme vibration and humidity conditions. All parts and components must be approved by this Laboratory before being used in production.

This work consists of:

(a) Devising tests and evaluations which will enable the Laboratory to select the most suitable materials and components for production purposes

(b) Applying these tests to a variety of materials and components and then evaluating the results

(c) Distributing to suppliers prepared specifications for materials and components needed for production

(d) Performing tests and evaluations on a representative sample of materials, components, and finished products to determine if they meet required performance and reliability standards (Fig. 7).

The reliability consciousness of Delco Radio is illustrated by the Radio Engineering Department's procedure for accepting power transistors obtained from the Semiconductor Research and Engineering Department. Specifications for power transistors are sent from the Reliability and Specifications Laboratory to the Semiconductor Research and Engineering Department, which then prepares, tests, and delivers the finished transistors to the Radio Engineering Department. Before the transistors are accepted for production, however, a representative sample from each lot is thoroughly tested in the Reliability and Specifications Laboratory, to determine if they meet the required standards.

Other functions of the Laboratory are to issue reports on the results of its tests, and to participate in the development of new products and in the improvement of existing products.

Service Groups

The four service Groups in the Radio Engineering Department supplement the work of the four main Groups and help maintain liaison with Delco Radio's customers.

The Model Shop, like its counterpart in the Semiconductor Research and Engineering Department, makes handmade models of various Delco Radio products for evaluation by design engineers and customers. Each year 250 to 300 models are produced, many of which are supplied to customers for installation in test cars.

Layout and detail drawings of products are prepared in the Department's drafting room which turns out every year about 1,400,000 sq ft of blueprints and about 8,000 drawings.

In addition to the main engineering staff in Komoko, Indiana, a three-man staff is stationed in Detroit for customer contact and test evaluation work, and a contact engineer is maintained in the Chicago plant of Delco Radio to handle any engineering production problems that arise.

Conclusion

Progress and refinement of research and engineering programs are perpetual assignments for the management of any industrial activity. These reponsibilities are magnified at Delco Radio, however, since the electronics field is an area in which the greatest advances probably are still in the future. As the world moves into the space age, tomorrow's engineer and scientist will be expected to explore many new technological avenues in order to solve the demands for complex, but reliable, electronic products. At Delco Radio, this means a constant improvement in research and engineering methods, facilities, and people.

A Teacher Looks at Hyatt

By GAIL B. KOPLIN

Gail B. Koplin is chairman, Mathematics Department, Watchung Hills Regional High School, Warren Township, Plainfield, New Jersey. This article was written by Mr. Koplin following his 1960 summer employment at Hyatt Bearings Division, Harrison, New Jersey, as a participant in the fifth General Motors Summer Program for High School Science and Mathematics Teachers. In this program, GM Divisions and Central Office Staffs may employ local high school science or mathematics teachers to provide them with additional technical information and work experience, which is helpful in their regular teaching activities. The program is concluded with a one-week conference at the GM Technical Center, which includes visits to other GM facilities in the southeastern Michigan area. The Educational Relations Section, Public Relations Staff, coordinates these activities.

LATE ONE Monday morning (8:30 a.m.—school begins earlier than this), a young high school mathematics teacher reported to the Administrative Office of Hyatt Bearings Division to begin summer employment. Following the usual procedure of signing the necessary papers and taking a physical examination, the first order of business was a fast tour of the section in which his services were to be performed. The new employe was shown equipment and technical apparatus understood perhaps only by a scientific wizard, or at least it seemed that way at the time.

Finally, after meeting everyone in the department (only a clergyman meets more people in a shorter time), the teacher was assigned a desk for one week. This was to be changed weekly as other employes took their vacation. The immediate task at hand was placed on the desk—a book on statistics written by a member of the GM Research Laboratories. Instructions: "Read the text and if you have any questions someone will try to help you find the answer." The employe read, and read, and reread until finally a few questions were evident. In answer to the questions, more texts were given out until the scholar was surrounded by three books and many pamphlets on the subject.

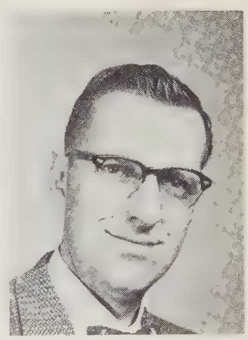
It was soon learned that an engineer is presented with a problem for which no solution is known. It is his task to seek a method of solution and to communicate to others his interpretation of results of experimentation. Little or no attempt is made by the administration to tell the engineer that a particular approach to the problem has to be used. The engineer is left to his own initiative and knowhow to find a solution. It was in this way that this summer employe found that an engineer can do his greatest work. The engineer attacks each problem with his own analytical method. He simply sets up a plan of attack. He experiments with various ideas, each time meeting with failure until the last time when he succeeds and the problem is solved.

During weeks of reading and writing, the summer employe lived with engineers and other technical personnel. Dinner conversations taught him that engineers have normal problems in life—they have baby pictures to show each other and they have hobbies such as electronics, boat building, making tours of New York City, planning lawns, taking wives to the doctor, and the like. Yes, they are human beings. But, in addition to leading normal lives they have work to do in the plant. They are not watched continuously but rather they work individually and in groups at their own pace and on their own initiative. They report to work on time, no time clocks to punch, and in general, they are given freedom which only reliable people can accept.

One observation—engineers spend much time in conversation and in writing. In essence, they have a profound problem in communicating their ideas from one to another. They argue, they agree and they disagree, and in a final analysis, they come up with a solution to the problem. More often than not, the solution to a problem leads to countless other problems which are then assigned as projects. When the engineer ceases to have a problem he is dispensable, but this never seems to happen. The inquisitiveness of the engineer generates new and more difficult problems and produces new and more complex products for society.

The task assigned to this summer employe culminated in a written report on the subject entitled, "Evaluation of Bearing Performance Test Results—The Weibull Analysis" followed by several lectures explaining the techniques involved. Since this employe had more than a passing acquaintance with statistics, he was asked to synthetize available literature on the Weibull method of analyzing fatigue and demonstrate how it could be applied to a typical set of engineering laboratory fatigue test data. Although the task seems to have been solved momentarily, there are many new problems to be solved stemming from this one task. This seems to be the life of the typical engineer—one problem solved and countless others now awaiting solution. There is no final solution to any problem since the task ahead is limited only by time and finance.

Having spent eight weeks in the employ of Hyatt Bearings, this employe finds that the company is but a group of warmhearted individuals who have a common purpose. These people live together in a wide variety of environments and work toward a common goal. This goal is to produce a new and better product which the user will purchase at a price that he can afford. To this end, a would-be employe of Hyatt Bearings might be cautioned that his productivity is limited only by his own personal resources, education, and initiative.



GAIL B. KOPLIN is Chairman of the Mathematics Department, Watchung Hills Regional High School, Warren Township, Plainfield, New Jersey. He received his bachelor's degree from Muhlenberg College. Graduate work at Montclair State College, Rutgers University, Newark State College, and the University of Illinois led to his master's degree. He is President of the Association of Mathematics Teachers of New Jersey and is a member of the New Jersey Education Association.

United States Patents as Prior Art

By CREIGHTON R. MELAND

Patent Section

Dayton Office

Prompt filing of patent application may benefit the would-be inventor

"LACK OF novelty" is one of several statutory grounds on which an applicant for a United States patent may be refused a patent on what he thought was an invention or on which a United States patent may be held invalid if it is inadvertently granted. Novelty is said to be lacking whenever the supposed invention was known or used by others in this country or was patented or described in a printed publication in this or in any foreign country prior to the applicant's date of invention.

A United States patent is by far the most effective means for showing lack of novelty in a later filed United States application. In the first place, it is, as of the date it was issued, a printed publication of everything shown or described therein whether claimed or not. In the second place, it is a favored kind of reference in that it is accepted as proof that knowledge by others of everything shown or described therein existed as of the filing date of the application on which it was issued. In other words, a United States patent is effective as of its filing date for showing lack of novelty in a later filed United States application whereas other printed publications are effective for that purpose only as of their publication dates.

This favored status of a United States patent was specifically recognized in 1926 by the Supreme Court of the United States in the case of *Alexander Milburn Company versus Davis-Bournonville Company, 270 U.S. 390, 46 Sup. Ct. Rep 234.* In this case, the plaintiff alleged infringement of its Whitford patent. The defendant defended on the ground that the patent was invalid for lack of novelty. In support of its position, the defendant cited a Clifford patent which admittedly disclosed the subject matter claimed by Whitford. The Clifford patent had a date of issue after the filing date of the Whitford patent but it had been issued on an application filed two months prior to the filing date of the application on which the Whitford patent had issued. Whitford was unable to prove a date of invention prior to the filing date of the Clifford application.

The question before the Supreme Court was whether the Clifford patent was effective as of its publication date—that is, its date of issue—or whether it was effective as of its filing date for showing lack of novelty of the subject matter claimed in the Whitford patent. If it was effective only as of the date of issue, then the Whitford patent was valid. On the other hand, if it was effective as of its filing date, then the Whitford patent was invalid for lack of novelty.

The Supreme Court held that the Clifford patent was effective from its filing date as proof of prior knowledge of the invention and that the Whitford patent was invalid. In its decision, the Court made the following statements:

> "The delays of the Patent Office ought not to cut down the effect of what has been done. The description shows that Whitford was not the first inventor. Clifford had done all that he could do to make his description public. He had taken steps that would make it public as soon as the Patent Office did its work, although, of course, amendments might be required of him before the end could be reached. We see no reason in the words or policy of the law for allowing Whitford to profit by the delay and make himself out to be the first inventor when he was not so in fact, when Clifford had shown knowledge inconsistent with the allowance of Whitford's claim . . . and when otherwise the publication of his patent would abandon the thing described to the public unless it already was old."

This case still represents the law in this country and the rule recognized in it was actually incorporated into our patent statutes in 1952.

Publications such as magazine and newspaper articles and foreign patents do not enjoy the same status as United States patents as a basis for showing lack of novelty in United States patent applications and patents since such other publications have no retroactive effect. This rule was specifically recognized to be the law in 1956 by the Court of Customs and Patent Appeals in the case of *In re Schlitter and Uffer, 110 U.S.P.Q. 304, 43 C.C.P.A. (Patents) 986.* In this case, the Patent Office had cited an article from *The Journal of the American Chemical Society* as a basis for rejecting a patent application. The article had a publication date that was later than the filing date of the patent application and it was conceded that the article was not a proper basis for rejecting the application if limited to this date. The article did, however, bear the notation "Received April 30, 1948" which date was prior to the filing date of the patent application. The Patent Office argued on analogy to the Milburn versus Davis-Bournonville case that the article should be given effect as of April 30, 1948, since the publisher at that time had received the article and all that was required to make it public was the actual printing and distribution of the article. The Court held that the article should not be given retroactive effect to the day it was received by the publisher and that it was therefore improper to reject the patent application on the basis of the article. The Court pointed out that the publishing of the article did not establish either an actual or constructive reduction to practice of the invention. It contrasted this case with the Milburn versus Davis-Bournonville case by stating that in the case of a United States patent, the filing of the patent application establishes a constructive reduction to practice of the invention.

From the foregoing, it is apparent that a United States patent is unusually effective as prior art against later filed United States patent applications. It is a printed

publication as of its date of issue and as such constitutes a statutory bar against applications claiming anything shown or described therein and filed more than one year later. It also shows knowledge of everything illustrated or described therein as of its filing date. To this extent, while not a statutory bar as of its filing date, it is, nevertheless, for the purpose of showing lack of novelty, the equivalent of a public disclosure of everything shown or described therein months and even years ahead of its date of issue. A United States patent also constitutes, as of its filing date, a constructive reduction to practice of the invention disclosed therein which for the purpose of proving completion of the invention is the full equivalent of the building and successful testing of a working model.

Summary

All this points up how desirable and important it is for an inventor to submit his ideas to his patent attorney promptly in order that, if the ideas have novelty and invention, applications for United States patents may be filed thereon as soon as possible. If this is not done the inventor may find himself unable to obtain a patent because of a prior application on a later invention or even unable to defend himself against a patent obtained by a later inventor who acted more promptly in getting his application filed.

Notes About Inventions and Inventors

Contributed by
Patent Section
Dayton Office

The following is a general listing of patents granted in the names of General Motors employes during the period July 1, 1960, through September 30, 1960.

AC Spark Plug Division
Flint, Michigan

• **William F. Thornburgh,** (*B.S.M.E., Michigan State University, 1951*) project engineer, inventor in patent 2,943,699 for an air cleaner and silencer assembly.

• **James A. Norton,** (*associate in science degree, Flint Junior College, 1934; S.B. degree, 1936; and Ph.D. degree in organic chemistry, 1939; University of Chicago*) research scientist, inventor in patent 2,943,737 for a filter and method for purifying oil.

• **David G. Keil,** project engineer; **Alvin H. Schmidt,** (*General Motors Institute*) designer; and Jesse E. Eshbaugh, retired, inventors in patent 2,946,215 for a press on closure for filler pipes.

• **Owen A. Christensen,** (*Technical School of Copenhagen, Denmark*) development specialist, inventor in patent 2,946,912 for spark plugs.

• **Richard L. Comer,** (*B.S.Cer.E., University of Illinois, 1952*) ceramic engineer, inventor in patent 2,949,376 for composition for glass to metal seal.

• **William S. Hayes,** (*B.S.M.E., University of Michigan, 1952*) project engineer, inventor in patents 2,950,364 and 2,952,011 for a warning device and signal mechanism, respectively.

• **Edwin F. Katz,** (*M.S.M.E., The Ohio State University, and B.S.M.E., University of Wisconsin*) manager, Reliability—Inertial Components, inventor in patent 2,950,430 for an electromagnetic torque motor system.

• **Joseph P. Casassa,** (*B.S.E.E., Michigan State University, 1954*) project engineer, inventor in patent 2,951,447 for impeller pumps with magnetic drives.

• **John D. McMichael,** (*Michigan State University*) senior project engineer, inventor in patent 2,954,091 for a cleaner silencer assembly.

• **Wesley W. McMullen,** (*B.S.M.E., University of Michigan, 1934*) staff engineer, inventor in patent 2,954,096 for a cleaner silencer assembly.

Allison Division
Indianapolis, Indiana

• **Chester E. Hockert,** (*B.S.M.E., Armour Institute, 1937, and M.S.M.E., Cornell University, 1941*) chief engineer, Turbo-Jet Engineering Department, and **Leslie R. Smith,** (*International School of Correspondence*) chief draftsman, Turbo-Jet Engineering Department, inventors in patent 2,945,673 for a segmented stator ring assembly.

• **Hamilton L. McCormick,** (*E.E. and M.E. degree, Johns Hopkins University, 1922, 1924*) special assignment, inventor in patent 2,949,278 for a turbine blade retention.

• **Paul Bancel,** (*B.A., Wesleyan University, 1937; University of Michigan*) engine project engineer; **Victor W. Peterson,** (*B.S.-M.E., Rose Polytechnic Institute, 1939*) engineer; and Herbert H. Schnepel, retired, inventors in patent 2,949,771 for a torque meter.

• **Robert P. Atkinson,** (*B.S.M.E., Purdue University, 1935 and B.S.M.E., Bradley University, 1940*) senior project engineer, and **Frederick W. Hoeltje,** (*B.S.M.E., Bradley University, 1940*) senior project engineer, inventors in patent 2,951,337 for a turbine air system.

• **Cyril M. Hawkins**, (*B.S.M.E., University of Toledo, 1948*) senior project engineer, inventor in patent 2,951,540 for a propeller brake.

• **Victor W. Peterson***, inventor in patent 2,951,543 for a thrust responsive mechanism.

• **Howard W. Christenson**, (*B.S., Oregon State College, 1938*) head, Research Department, and **William G. Livezey**, (*M.E., International School of Correspondence, 1937*) chief designer, Transmission Engineering Department inventors in patent 2,953,040 for a transmission.

• **Frank G. Leland**, (*Millikin University*) senior designer, inventor in patent 2,953,348 for blade fastenings.

• **Sidney A. Rains**, (*B.M.E., General Motors Institute, 1949*) senior project engineer, inventor in patent 2,953,939 for a transmission.

*Inventors' names marked with an asterisk have biographical listings noted previously in this issue's Notes About Inventions and Inventors.

• **Douglas Johnson**, (*Arkansas Polytechnic, 1936*) chief, preliminary design section, and **Russell S. Hall**, chief, preliminary design engineering, inventors in patent 2,952,973 for a turbofan-ramjet engine.

Aeroproducts Operations
Allison Division
Vandalia, Ohio

• **Howard M. Geyer**, (*B.S.I.E., University of Alabama, 1940*) chief research engineer, inventor in patents 2,945,387 and 2,953,119 for a rotary actuator and a hydraulic actuator assembly with oil circulating means, respectively.

• **Ward Bunker**, (*Anderson Trade School, Sinclair College*) experimental engineer, inventor in patent 2,945,547 for an engine and vehicle speed control governor.

• **Darrell E. Royer**, (*Sinclair College and University of Dayton*) senior designer, inventor in patent 2,948,263 for propeller torque unit construction.

• **Francis E. Conn**, (*B.S.E.E., University of Tennessee, 1951*) project head, design engineering, and James R. Kessler, no longer with GM, inventors in patent 2,948,343 for a propeller mechanism.

• **Dale W. Miller**, (*B.S., Wittenberg College, 1934*) assistant chief engineer; **Robert K. Skinner**, (*B.S.E.E., University of Cincinnati, 1943*) senior project engineer, and James R. Kessler*, inventors in patent 2,949,159 for a propeller speed controller.

Buick Motor Division
Flint, Michigan

• **Eric R. Dietrich**, senior project engineer, and Edwin G. Peckham, retired, inventors in patent 2,945,701 for a pneumatic vehicle suspension system.

• **Leonard M. Morrish**, (*Michigan State University*) staff engineer, and **Lloyd E. Muller**, (*B.S.M.E., University of Kansas, 1929*) director, Experimental Engineering, inventors in patent 2,949,165 for a muffler.

• **Leonard M. Morrish***, and **William D. Pittsley**, now with AC Spark Plug Division, inventors in patent 2,951,724 for a bumper exhaust.

• **Archie D. McDuffie**, (*General Motors Institute, 1934*) staff engineer, inventor in patent 2,953,361 for a fuel injection system.

• **Donald C. Scoville**, (*B.S.M.E., University of Michigan, 1951*) senior project engineer, inventor in patent 2,943,847 for a fuel injection flow control valve.

Business Research Staff
Detroit, Michigan

• **Andrew T. Court**, (*A.B., Vanderbilt University, 1924*) economist, inventor in patent 2,953,961 for a Fresnel prism or lens built into the rear window making it possible to mount a 16-in., rear-view

mirror completely above the windshield, thus providing panoramic hindsight as well as an unobstructed view ahead.

Cleveland Diesel Engine Division
Cleveland, Ohio

• **Donald W. Adams,** (*B.S., Case Institute of Technology, 1942*) senior project engineer, and **Gerhard K. Weber,** (*Technical College of Berlin-Charlottenburg*) chief mechanical engineer, inventors in patent 2,953,127 for a fluid pressure engine starting system.

Delco Appliance Division
Rochester, New York

• **Eugene R. Ziegler,** (*University of Rochester*) special development engineer, inventor in patent 2,947,185 for a windshield wiper drive mechanism and in patents 2,953,802 and 2,953,803, both for a windshield cleaning system.

• **Walter D. Harrison,** project engineer, inventor in patent 2,949,053 for a windshield wiper actuating mechanism.

• **Francis M. Ryck,** (*B.S., University of Rochester, 1950*) assistant supervisor, windshield wiper applications; **Cyril T. Wallis,** (*Technical School, Cambridge, England*) patent and new devices contact; and Henry C. Rohr, retired, inventors in patent 2,952,865 for a squeegee.

Delco Moraine Division
Dayton, Ohio

• **Paul R. Allison,** (*B.S., Education, University of Dayton, 1951*) process engineer, inventor in patent 2,944,945 for electroplating.

• **Holle C. Luechauer,** (*A.B., University of Cincinnati, 1927*) senior experimental chemist, inventor in patent 2,944,947 for electroplating method and apparatus.

• **John W. Arnett,** (*B.S., Education, University of Dayton, 1953*) laboratory technician, and **Thomas G. Ankeny,** Pontiac Motor Division, inventors in patent 2,945,291 for friction material.

• **William A. Luther, Jr.,** (*B.S., Carnegie Institute of Technology, 1942*) senior metallurgist, and **Roland P. Koehring,** (*Earlham College*) research engineer, inventors in patent 2,945,292 for friction material.

• **Arthur R. Shaw,** (*B.M.E., The Ohio State University, 1937*) assistant chief engineer and **Frederick W. Sampson,** (*M.E., Cornell University, 1924*) section engineer on special assignment, inventors in patent 2,945,759 for a method for measuring the strength of sintered ferrous articles.

Delco Products Division
Dayton, Ohio

• **Edwin F. Rossman,** (*Case Institute of Technology, B.S.M.E., Massachusetts Institute of Technology, and Harvard University, 1920*) research engineer, inventor in patents 2,943,711 and 2,944,638 for a rod seal for shock absorber and a device to prevent movement beyond predetermined rate, respectively.

• **Ralph K. Shewmon,** (*General Motors Institute, 1934*) assistant chief engineer and **George A. Neyhouse,** (*E.E., Rose Polytechnic, 1939*) senior project engineer, inventors in patent 2,944,126 for a control for fluid suspension system.

• **John F. Pribonic,** (*B.S.M.E., Princeton University, 1947*) staff engineer, inventor in patent 2,950,124 for a fluid suspension system with vehicle height and roll control.

• **James E. Whelan,** (*B.M.E., University of Illinois, 1951*) project engineer, inventor in patent 2,953,391 for an air suspension control valve.

Detroit Transmission Division
Ypsilanti, Michigan

• **Robert W. Stapleton,** (*B.S., Michigan College of Mining and Technology, 1936*) assistant chief engineer, inventor in patent 2,943,501 for a transmission control.

• **Walter B. Herndon,** (*B.S.E., State College of Washington, 1928, and M.S.E., University of Michigan, 1930*) director of engineering and sales, inventor in patent 2,943,516 for a transmission.

• **Carl F. Kop**, (*Berlin, Germany, Technical College; University of Detroit*) staff engineer, inventor in patent 2,946,240 for overdrive units and control therefor.

• **Kenneth E. Snyder**, senior project engineer, inventor in patent 2,946,241 for a transmission.

• **Jack R. Doidge**, (*M.E., Iowa State University, 1940; M.A.E., Chrysler Institute, 1942*) chief engineer, and Victor C. Moore, no longer with GM, inventors in patent 2,947,199 for a transmission.

• **Milton H. Scheiter**, (*General Motors Institute, 1943*) section engineer, inventor in patent 2,951,694 for a governor drive for hydraulic transmission.

• **Darrel R. Sand**, (*B.M.E., General Motors Institute, 1949*) assistant staff engineer, inventor in patent 2,954,103 for a brake mechanism.

Diesel Equipment Division
Grand Rapids, Michigan

• **Richard G. Grundman**, (*B.S.M.E., Stevens Institute of Technology, 1951*) project engineer, inventor in patent 2,954,172 for a liquid spray nozzle.

Electro-Motive Division
La Grange, Illinois

• **Willard R. Stigler**, senior project engineer, and **Walter Drabik**, senior designer, inventors in patents 2,945,139 and 2,945,140 for method and wedges for conducting heat from slots of dynamoelectric machine and dynamoelectric machine slot wedges.

• **Albert N. Addie**, (*B.S.M.E., Illinois Institute of Technology, 1944, and M.S.M.E., Case Institute of Technology, 1947*) chief research engineer; **Hugh C. Lafferty**, (*B.S.M.E., Purdue University, 1941*) combustion control development engineer; and **Hugh A. Williams, Jr.**, (*B.S.M.E., 1948 and M.S., 1950, North Carolina State University*) senior project engineer, inventors in patent 2,949,541 for a power plant control.

• **Kenneth D. Swander, Jr.**, (*B.S.M.E., Purdue University, 1942*) assistant air brake engineer, inventor in patent 2,954,238 for railway vehicle air suspension.

These patent listings are informative only and are not intended to define the coverage which is determined by the claims of each one.

GM Engineering Staff
Warren, Michigan

• **William C. McIntyre**, (*B.I.E., General Motors Institute, 1943*) assistant engineer in charge, Structure and Suspension Development Group, and **Von D. Polhemus**, (*B.S.M.E., University of Cincinnati, 1933*) engineer in charge, Structure and Suspension Development Group, inventors in patent 2,945,700 for fluid suspension having quick centering control for electrically actuated valves.

• **Andries C. deWilde**, (*M.M.E., 1928 and M.E.E., 1931, Technical University of Delft, Holland*) senior project engineer, inventor in patent 2,949,237 for a modulating valve control system.

• **Stanley H. Mick**, (*B.M.E., General Motors Institute, 1955*) project engineer, inventor in patents 2,954,019 and 2,954,022 for a fuel cut-off mechanism for fuel injection system and a split engine, respectively.

Fisher Body Division
Warren, Michigan

• **Joseph G. Joachim**, senior drafting room checker, and **Alfred B. Sauer**, (*B.S.E., Engr. Mech., University of Michigan, 1952*) experimental engineer, Chevrolet Motor Division, inventors in patent 2,943,880 for a closure latch.

• **George D. Legge**, (*Western Technical Institute, Toronto, Canada*) senior project engineer, inventor in patent 2,944,145 for a dome and reading lamp assembly.

• **Napoleon P. Boretti**, (*B.E.E., University of Detroit, 1935*) assistant engineer in charge, Process Development Department, and **Larrabee T. Kendall**, (*B.M.E., General Motors Institute, 1947*) senior

project engineer, inventors in patent 2,945,513 for a method of producing seat frames.

• **Robert E. Allan,** (*B.M.E., University of Detroit, 1933*) engineer in charge, Process Development Laboratory, inventor in patent 2,946,246 for a drill fixture.

• **Peter P. Dusina, Jr.,** (*B.S.E.E., University of Detroit, 1954*) senior production engineer, and **Ralph M. Stallard,** (*B.S.E.E., Michigan College of Mining and Technology, 1949*) senior production engineer, inventors in patent 2,946,713 for a process for embossing decorative articles.

• **David D. Campbell,** (*B.M.E., General Motors Institute, 1953*) assistant engineer in charge, Experimental and Development—Mechanical Design Group, and **Claud S. Semar,** (*Detroit City College, University of Michigan, and Wayne State University*) senior project engineer, inventors in patent 2,947,025 for a hinge.

• **David D. Campbell***, and **Louis P. Garvey,** (*B.M.E., University of Detroit, 1940*) assistant engineer in charge, Product Engineering Activity, inventors in patent 2,948,917 for a hinge assembly.

• **Ralph M. Stallard***, inventor in patent 2,948,929 for dielectric embossing.

• **Horace Tomlinson,** plant contact engineer, inventor in patent 2,949,872 for a sewing machine attachment.

• **Engelbert A. Meyer,** senior project engineer, inventor in patent 2,949,986 for a fastening device.

• **Louis P. Garvey*** and Earl M. Starr, no longer with GM, inventors in patent 2,953,188 for a vehicle seat.

• **Louis P. Garvey***, inventor in patent 2,953,801 for a windshield washer pump.

Frigidaire Division
Dayton, Ohio

• **Leonard J. Mann,** (*M.E. University of Cincinnati, 1940*) senior project engineer; **John M. Murphy,** (*B.S.E.E., Purdue University, 1930*) manager, Compressor Engineering Department; and **Clifford H. Wurtz,** (*B.S., University of Illinois, 1929*) manager, Refrigerated Appliances Engineering, inventors in patent 2,944,410 for refrigerating apparatus.

• **Ira L. Gould,** (*B.S.M.E., New Mexico Agricultural and Mechanical Arts College, 1948*) senior project engineer, and **Richard E. Thompson,** (*B.S.M.E., University of Cincinnati, 1949*) senior project engineer, inventors in patent 2,945,362 for an air conditioner.

• **Richard S. Gaugler,** (*B.S.Ch.E., Purdue University, 1922*) supervisor of major product line, inventor in patent 2,945,954 for refrigerating apparatus.

• **Byron L. Brucken,** (*B.S. degree, University of Dayton, 1956*) senior project engineer, inventor in patent 2,946,489 for automatic soap dispenser for washing machines.

• **Robert D. Bremer,** (*B.S.E.E., Purdue University, 1934*) senior project engineer, inventor in patent 2,948,801 for a domestic appliance.

• **Everett C. Hutchins,** (*Eastern State College*) foreman—welding machine repair, Maintenance Department, inventor in patent 2,949,319 for a pipe coupling between relatively hard and soft tubes.

• **Kenneth O. Sisson,** (*B.S.M.E., South Dakota State College, 1936*) senior project engineer, inventor in patent 2,949,759 for a domestic appliance.

• **Millard E. Fry,** (*B.S.M.E., University of Pittsburgh, 1931*) senior project engineer, inventor in patent 2,951,435 for a domestic appliance.

• **Richard E. Gould,** (*B.S.M.E., 1923, and M.S.M.E., 1927, University of Illinois*) chief engineer, Research and Future Products Engineering, inventor in patent 2,951,650 for a garbage grinder.

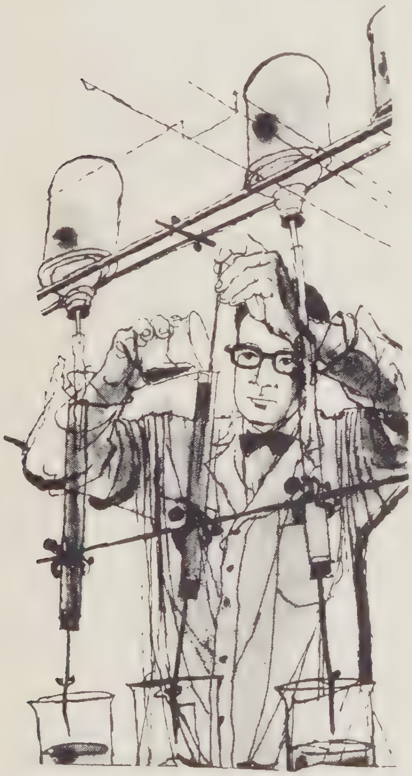
• **Ira L. Gould***; **Edward A. Van Schaik,** (*B.M.E., General Motors Institute, 1957*) project engineer; and **Harvey R. Tuck,** (*B.S.M.E., 1949, and M.S.M.E., 1950, Massachusetts Institute of Technology*) senior engineer, inventors in patent 2,952,989 for an air conditioner with controlled reheat.

• **Harvey C. Black, Jr.,** (*Associate Degree, Sinclair College, 1960*) senior special tester, and Kenneth R. Partington, no longer with GM, inventors in patent 2,952,994 for an air conditioner element arrangement.

• **Byron L. Brucken*** and **Kenneth O. Sisson***, inventors in patent 2,953,006 for a washing machine dispensing cup.

• **George B. Long**, (*B.S.E.E., Purdue University, 1937*) supervisor of major product line, inventor in patent 2,953,357 for a refrigerator with heating means.

• **Verlos G. Sharpe**, (*B.S.M.E., Purdue University, 1948*) section engineer, Refrigerated Appliances Engineering Department, inventor in patent 2,953,909 for a refrigerator cabinet illuminating means.



GMC Truck and Coach Division
Pontiac, Michigan

• **Hans O. Schjolin**, (*B.S. degree, Karlstad College, Sweden, 1920, and Polytechnical Institute, Mittweida, Germany, 1923*) staff engineer, inventor in patent 2,944,618 for a hydraulic cooling system for brakes, transmissi on torque converter, and and differential.

• **Samuel L. Wallwork**, (*Associate Engineering Degree, Pennsylvania State University, 1955*) layout draftsman, and **Irwin K. Weiss**, now with Chevrolet Motor Division, inventors in patent 2,951,548 for tilt cab for trucks.

Guide Lamp Division
Anderson, Indiana

• **Robert L. Zook**, designer, inventor in patent 2,945,947 for a spotlight.

Harrison Radiator Division
Lockport, New York

• **Edward F. Lewis**, senior designer in charge, Car Heater Section, inventor in patent 2,945,712 for a hub and shaft arrangement.

Inland Manufacturing Division
Dayton, Ohio

• **Russell J. Bush**, (*B.S.Ch.E., Purdue University, 1925*) project engineer, and **Orville C. DeWeese**, extruding die foreman, inventors in patent 2,945,390 for a transmission belt and the like.

• **Harold J. Reindl**, (*B.Ch.E., University of Dayton, 1942*) section head, Paints, Coatings, and Adhesives Laboratory, inventor in patent 2,947,281 for a manufacturing apparatus and method of operating the same.

• **Harry Otto Waag**, Paint Laboratory, inventor in patent 2,948,651 for a plastic article and method of producing same.

• **Edward P. Harris**, (*M.E., Cornell University, 1931*) section engineer, inventor in patent 2,949,956 for a seat construction.

• **Frederick Sampson**, (*M.E., Cornell University, 1924*) section engineer, on special assignment from Delco Moraine Division, inventor in patent 2,951,562 for a brake structure.

New Departure Division
Bristol, Connecticut

• **Charles N. Hay**, (*B.S.M.E., The Ohio State University, 1934*) resident engineer, AC Spark Plug Division, inventor in patent 2,946,160 for a method and apparatus for finishing annular grooves.

Oldsmobile Division
Lansing, Michigan

• **Gilbert Burrell**, (*B.S.E.E., Michigan State University, 1928*) motor engineer, inventor in patent 2,945,715 for a fluid seal.

Pontiac Motor Division
Pontiac, Michigan

• **Elliott M. Estes**, (*General Motors Institute, 1938; B.S.M.E., University of Cincinnati, 1940*) chief engineer, inventor in patent 2,945,723 for a wheel cover.

• **Leslie S. Thomas**, chief electrician, inventor in patent 2,946,865 for an electric control box.

GM Research Laboratories
Warren, Michigan

• **Robert F. Thomson**, (*B.S.M.E., 1937; M.S.M.E., 1940; and Ph.D., 1941, University of Michigan*) head, Metallurgical Engineering Department; **Carl F. Joseph**, Central Foundry Division; and Philip R. White, no longer with GM, inventors in patent 2,943,932 for a ferrous metal.

• **Alfred L. Boegehold**, (*M.E., Cornell University, 1915*) consultant, inventor in patent 2,945,272 for a process and apparatus for forming reinforced thin walled shell molds.

• **William F. King**, (*General Motors Institute, 1940 and B.S.M.E., University of Michigan, 1941*) assistant head, Special Problems Department, inventor in patent 2,947,172 for a balancing organization.

• **William F. King***, and Kauno E. Sihvonen, no longer with GM, inventors in patent 2,947,175 for a balancing device.

• **Joseph F. Lash**, (*B.S.M.E., Michigan State University, 1938*) supervisor, Special Problems Department, inventor in patents 2,947,173 and 2,947,174 for an automatic balancing installation and balancing organization, respectively.

• **Walter E. Sargeant**, (*B.S.E.E., University of Michigan, 1926*) senior research engineer, inventor in patent 2,949,583 for a timing control circuit.

• **Warren H. Smith**, (*B.S.M.E., Purdue University, 1928*) supervisor of design, Mechanical Development Department, inventor in patent 2,949,792 for a differential assembly.

Rochester Products Division
Rochester, New York

• **Howard H. Dietrich**, (*B.S.E.E., Purdue University, 1926, and Yale University*) patents, new devices and project analysis engineer; **John D. Hiller**, (*B.S.M.E., Rensselaer Polytechnic Institute, 1949*) AC Spark Plug Division; **Robert Lay**, (*B.S., Aviation, Parks College of St. Louis University, 1941*) AC Spark Plug Division; **Mark R. Rowe**, (*B.M.E., New York University, 1940*) head, Engine Control Department; and **Harry C. Zeisloft**, (*B.S.M.E., University of Iowa, 1941*) AC Spark Plug Division, inventors in patent 2,943,411 for an after burner control with enrichment at low compressor discharge pressure.

• **Milton C. Rohr**, (*Rochester Institute of Technology and General Motors Institute*) senior contact engineer, inventor in patent 2,946,575 for a carburetor air heating device.

• **Elmer Olson**, (*Lewis Institute*) engineering consultant; **George W. Wentis**, (*Rochester Institute of Technology, 1951*) group leader, design and drafting; and **Frederick R. Dennison**, Chevrolet Motor Division, inventors in patent 2,946,577 for a choke lock-out.

• **Howard H. Dietrich***, inventor in patent 2,949,903 for a charge forming device.

• **Lawrence C. Dermond**, (*Purdue University and Tri-State College*) staff engineer, inventor in patent 2,954,018 for a cold start enrichment system.

Saginaw Steering Gear Division
Saginaw, Michigan

Arthur F. Bohnoff, (*B.S.M.E., Michigan College of Mining and Technology, 1938*) senior project engineer, and Stanley J. Skerl, no longer with GM, inventors in patent 2,943,510 for a transmission control.

• **Donald P. Marquis**, (*B.S.Chem.E., 1934 and M.S., 1939, Wayne State University*) assistant chief engineer, and **Raymond J. Schultz**, (*B.S.M.E., University of Michigan, 1950*) senior project engineer, inventors in patent 2,945,364 for a universal joint.

• **William B. Thompson**, (*B.M.E., General Motors Institute, 1950 and M.S., Massachusetts Institute of Technology, 1960*) assistant chief engineer, inventor in patent 2,946,503 for an air compressor.

• **Kenneth K. King**, (*B.S., U. S. Naval Academy, 1945*) senior project engineer, inventor in patent 2,947,158 for a universal joint centering device.

• **Earl W. Glover**, designer, inventor in patent 2,952,999 for shaft connections.

GM Styling Staff
Warren, Michigan

• **Julius Hezler, Jr.**, senior design engineer, inventor in patent 2,949,290 for a window regulator operating apparatus.

• **John Himka**, (*diploma in Aero.E., Academy of Aeronautics, 1941*) chief engineer, Body Development Studios, inventor in patent 2,949,331 for a vehicle seat assembly.

• **Anthony J. Ingolia**, (*M.S. in product design, Illinois Institute of Technology, 1952*) senior designer, inventor in patent 2,953,419 for a domestic appliance.

• **Arthur J. Carpenter**, senior engineer—experimental, inventor in patent 2,954,522 for a closure latch.

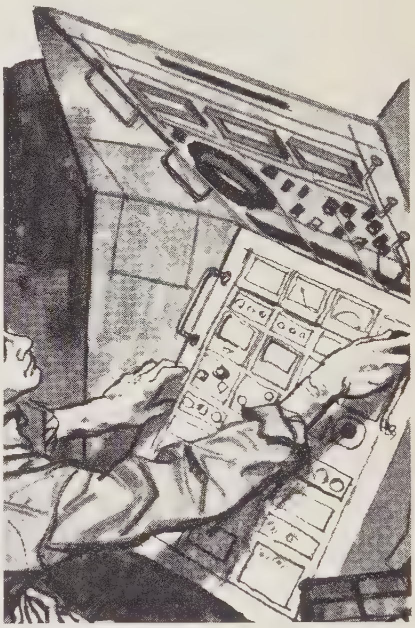
Ternstedt Division
Detroit, Michigan

• **George B. Horton**, (*B.S.E.E., Michigan State University, 1948*) senior project engineer, and **Thomas E. Lohr**, (*Tri-State College*) senior design engineer, inventor in patent 2,944,188 for an automatic light controlled headlamp means.

• **George B. Horton***, inventor in patent 2,945,722 for a seat adjuster.

• **Robert J. Heusel**, (*B.S.Met. and Chem. E., University of Michigan, 1936; M.Met.E., Columbia University, 1938*) works manager, Flint plant, inventor in patent 2,947,167 for a test fixture.

• **Theodore H. Johnstone**, senior design engineer, inventor in patent 2,949,762 for a lock.

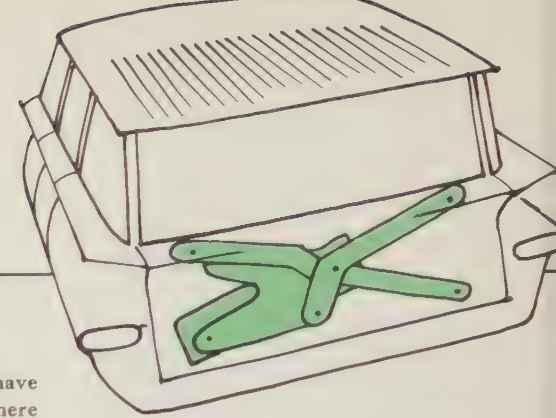


• **Barthold F. Meyer**, (*B.S.M.E., Pratt Institute, 1939, and Johns Hopkins University*) engineering group supervisor, Product Engineering Department, and **Nicholas Toruk**, (*B.S.M.E., University of Detroit, 1951*) senior project engineer, inventors in patent 2,950,138 for a closure latch.

• **Akira Tanaka**, (*B.S.M.E., Michigan State University, 1949*) design group leader, inventor in patent 2,953,190 for a vehicle seat adjuster.

A Typical Problem in Engineering:

Analyze the Mechanical Components of an Automotive Window Regulator Mechanism



The mechanical components of an automotive window regulator mechanism must have sufficient strength to meet specific functional requirements. The problem presented here is to analyze the various components of a window regulator mechanism when it is subjected to an applied torque to see if the preliminary design is adequate to meet the functional requirements. The problem also requires that a torsion-type counterbalance spring be designed which will be capable of balancing the weight of the window glass assembly when it is in the fully lowered position.

An automotive window regulator mechanism permits adjustment of the window from a fully closed position to a fully open position by means of a simple spindle rotation. The use of a friction clutch at the spindle location allows the window to remain in the position at which it was stopped during the raising or lowering operation.

The regulator mechanism is provided with a high mechanical advantage to overcome friction, to assure smooth operation, and to prevent reverse operation. (Reverse operation refers to the action of operating the regulator mechanism by applying a load through the glass, such as might occur during an attempted act of forced entry into the automobile.) Both the friction clutch and the high mechanical advantage of the mechanism resist any downward inertia forces of the glass assembly caused by road vibrations.

The main components of a window regulator mechanism, such as might be used for the tailgate window of a station wagon, are a spindle-mounted pinion, a sector plate, a lift arm, a balance arm, and a back plate (Fig. 1). The spindle-mounted pinion and sector plate comprise that portion of the regulator mechanism which provides the mechanical advantage. The pinion engages mating gear teeth located on the arc of the sector plate. Both the pinion and sector plate are mounted on the stationary back plate to assure proper engagement of the gear teeth.

The ratio between the pitch diameters of the pinion and sector plate equals the

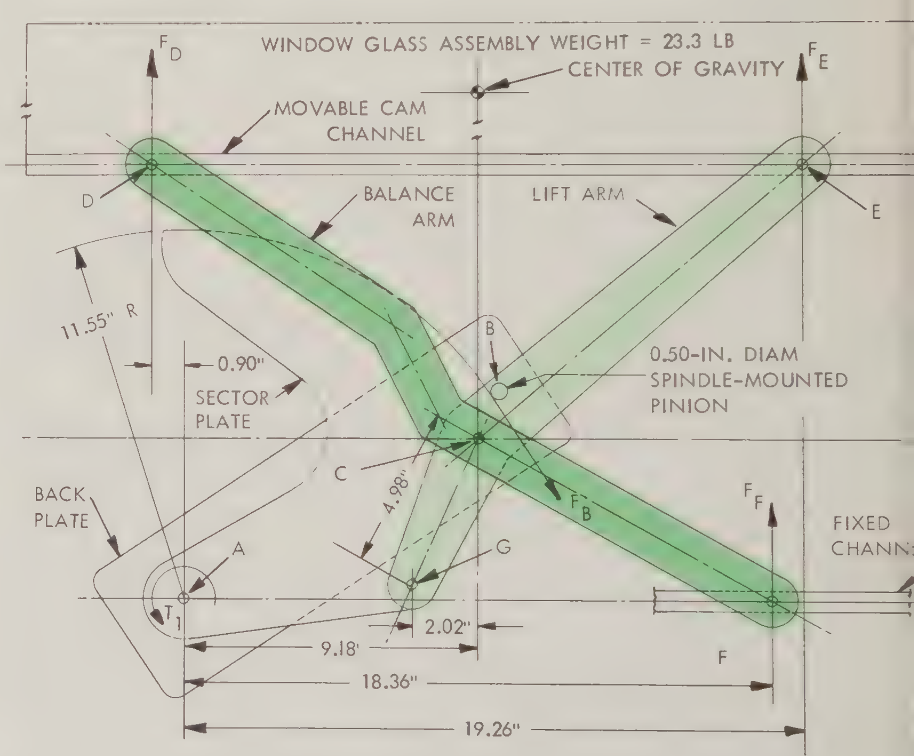


Fig. 1—An automotive window regulator mechanism, such as might be used in the tailgate window of a station wagon, is shown here in the fully raised position (left) and the fully lowered position (right). The main components of the mechanism are a sector plate, a back plate, a spindle-mounted pinion, a lift arm, and a balance arm. Rivets and pins are used to connect the main components.

The sector plate main pivot pin is located at point A. The full angular travel of the sector plate between the raised and lowered positions is 46°. Also located at point A is a torsion-type counterbalance spring (Fig. 2). The curved vector T_1 represents the output torque of the spring when the window is fully raised. When the window is fully lowered the output torque of the spring is represented by the curved vector T_2. A test load torque of 250 in-lb applied to the spindle-mounted pinion, located at point B, produces a moment of 11,550 in-lb around point A and a tangential force F_B tangent to the point of engagement between the pinion B and the sector plate.

By JOHN P. BURLEY
Fisher Body Division

Assisted by E. H. Eddy
General Motors Institute

Can the components withstand the applied stress?

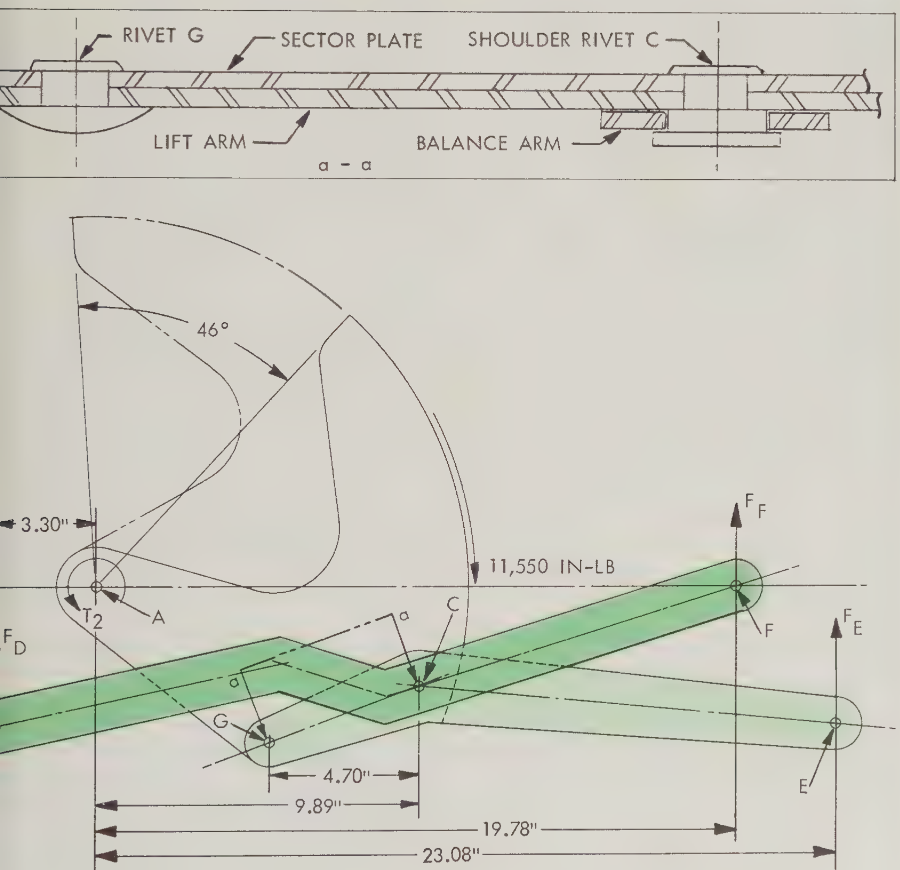
mechanical advantage of the mechanism. The mechanical advantage for the window regulator mechanism to be used in the problem to be presented is 46.2 to 1.

The lift arm is riveted to the sector plate at two points. The lift arm serves as an extension of the sector plate to provide the desired vertical travel from the arc through which the sector plate moves. The lift arm has a lift pin roller at its extreme upper end which is attached to a movable cam channel. The cam channel is attached to the bottom of the window glass assembly. The lift arm supports one-half of the weight of the glass assembly.

The balance arm has a pivot pin attachment to the lift arm and sector plate. Both ends of the balance arm have roller attachments. The upper end is attached to the movable cam channel by a lift pin in the same manner as the lift arm. The lower end of the balance arm is attached to a fixed cam channel. This permits only horizontal relative motion of the ends of the balance arm to take place when the regulator mechanism moves the window from a fully raised position to a fully lowered position. The balance arm supports the remaining half of the glass assembly weight.

Located at the main pivot point on the sector plate is a flat wire, torsion-type counterbalance spring (Fig. 2). This spring is keyed to the stationary back plate. The moving end of the spring is fastened to the sector plate. The output torque of the counterbalance spring opposes the external moment applied to the regulator by the glass and sash weight.

The remaining components of the window regulator mechanism consist of rivets and pivot pins used to connect the main components.



The balance arm has a center pivot pin at point *C*. This pin also serves to rivet the lift arm to the sector plate. The lift arm also is riveted to the sector plate at point *G*. The balance arm has a lift pin roller attached to a movable cam channel at point *D*. The lift arm has a similar pin roller attached to the movable cam channel at point *E*. The lower end of the balance arm is attached to a fixed channel by a pin roller at point *F*.

The 250 in-lb test load produces vertical reactions F_D, F_E, and F_F at points *D*, *E*, and *F*. These points are loaded in the vertical direction only because the pin rollers are free to move horizontally in the channels. The relationship between lift pins *D* and *E*, with respect to their distances from pivot pin *C*, is held symmetrical by the equal distance of points *A* and *F* to point *C* and by the common horizontal centerline of points *A* and *F*.

Regulator Mechanism Must Meet Functional Specifications

The window regulator mechanism must be designed to meet specific functional requirements. The requirements which the regulator mechanism used in the problem to be presented must meet are as follows.

The regulator mechanism assembly is bolted to a fixture in the same position it would assume when installed in the body. The lift pins attached at the ends of the lift arm and balance arm to the movable cam channel are then restrained by the cam channel against movement at either the nominal raised or lowered positions of the regulator mechanism. Under these conditions the mechanism must withstand a 250 in-lb torque, in either a clockwise or counterclockwise direction, applied at the spindle-mounted pinion and still be capable of full normal travel when loaded with one-half of the glass assembly weight at each lift pin.

The limitations in the strength of the regulator mechanism lie in the materials specified for use. The lift arm, balance arm, and sector plate are preferably made from a grade of steel suitable for high production stampings. The pins and rivets are made from cold rolled steel bar stock. The counterbalance spring must be made of a high carbon spring steel material.

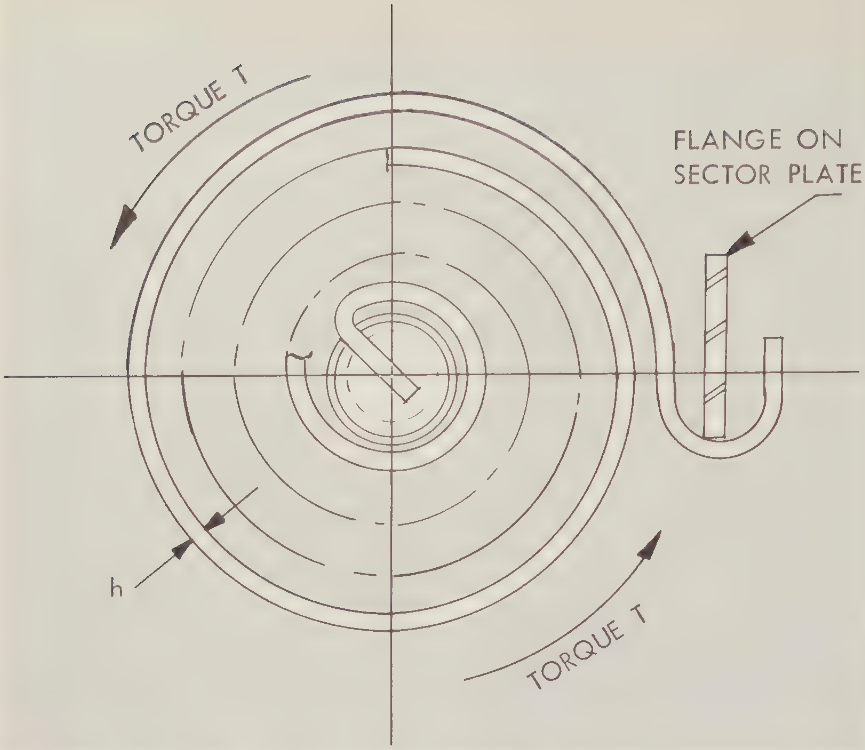


Fig. 2—A flat wire, torsion-type counterbalance spring of thickness h is used in the window regulator mechanism. The spring, which is keyed to the back plate, is located at the main pivot pin on the sector plate (point A, Fig. 1). The moving end of the spring is fastened to a flange on the sector plate.

PROBLEM DATA

SECTOR PLATE
- Pitch Diameter—11.55 in.
- Thickness—0.120 in.
- Material—S.A.E. 1010 (or comparable)
  - Allowable stress—32,500 psi (tensile)

LIFT ARM
- Width at Upper End (Point E)—1.60 in.
- Width at Center (Point C)—2.20 in.
- Width at Lower End (Point G)—1.40 in.
- Thickness—0.120 in.
- Material—S.A.E. 1010 (or comparable)

BALANCE ARM
- Width—1.65 in.
- Thickness—0.120 in.
- Material—S.A.E. 1010 (or comparable)

SPINDLE-MOUNTED PINION
- Pitch Diameter—0.25 in.

PIN AND RIVET DIAMETERS
- Sector Plate Main Pivot Pin (Point A)—0.50 in.
- Balance Arm Center Pivot Pin (Point C)—0.76 in. (shoulder size)
- Balance Arm Lower Roller Pin (Point F)—0.38 in.
- Lift Arm Rivet (Point C)—0.50 in.
- Lift Arm Rivet (Point G)—0.50 in.
- Lift Pins (Points D and E)—0.25 in.
- Material for all Pins and Rivets—S.A.E. 1030 Cold Rolled Steel
  - Allowable stress—36,000 psi (in shear)

PIN CLEARANCES
- All Pin Clearances—0.040 in.

GLASS ASSEMBLY
- Weight—23.3 lb

COUNTERBALANCE SPRING
- Desired Coil Width (Axial)—0.50 in.
- Desired Coil Length (Maximum)—65 in.
- Desired Spring Rate—2 in-lb per degree
- Material—S.A.E. 1050-1085
  - Allowable stress—200,000 psi (tensile)

Table I—Shown here are data to be used in the solution to the problem. Refer to Figs. 1 and 2 for a description of the components and points mentioned here.

Problem

The problem is divided into two parts. The first part requires that a torsion-type counterbalance spring be designed which will be capable of completely balancing the weight of the glass assembly when it is in the fully lowered position. The output torque of the spring must be sufficient to counterbalance the external moment of the glass assembly. The design specifications for the counterbalance spring should include the required radial thickness and the active length of the spring.

The second part of the problem involves analyzing the various components of the regulator mechanism to see if they are structurally adequate to withstand the bending moments resulting from the 250 in-lb torque applied to the spindle-mounted pinion under the conditions specified in the functional requirements. Determine the loads in the vertical directions at the lift pins for both the fully raised and fully lowered positions of the regulator mechanism. Summarize any changes that should be made in the present design of the main components.

Design data for the various components of the regulator mechanism are presented in Table I.

The solution to the problem will be presented in the April-May-June 1961 issue of the General Motors Engineering Journal.

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Higdon, A., and Stiles, W. B., *Engineering Mechanics* (New York: Prentice-Hall, Inc., 1948), p. 88.

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Technical Presentations by GM Engineers and Scientists

The technical presentation is another way in which information about current engineering and scientific developments in General Motors can be made available to the public. A listing of speaking appearances by General Motors engineers and scientists, such as that given below, usually includes the presentation of papers before professional societies, lecturing to college engineering classes or student societies, and speaking to civic or governmental organizations. Educators who wish assistance in obtaining the services of GM engineers and scientists to speak to student groups may write to the Educational Relations Section, Public Relations Staff, General Motors Corporation, General Motors Technical Center, Warren, Michigan.

The following GM personnel made recent technical presentations.

Automotive Engineering

A. L. Everitt, product section head, Inland Manufacturing Division, before the American Society of Mechanical Engineers, Erie, Pennsylvania, title: Automotive Engine Mount Design.

Clare D. Harrington, administrative engineer, Oldsmobile Division, before the Grand Ledge, Michigan, Lions Club, title: Styling a New Car.

John F. Boyle, design engineer, Detroit Diesel Engine Division, before the University of Michigan student section, Society of Automotive Engineers, title: Diesel Engine Compression Ratios and Combustion Chamber Shape.

From GMC Truck and Coach Division: **John G. Locklin**, chassis section engineer in charge of steering and suspension, before the Michigan Trucking Association, Detroit, title: The Future of Air Suspension in Truck and Tractor Operation; **William P. Strong**, coach engineer, before the annual meeting of the American Transit Association, Philadelphia, title: The First Year with the New Model; and **W. E. Whitmer**, project engineer, before the National Association of Furniture Manufacturers, Ann Arbor, Michigan, title: The Diesel Truck and its Possible Place in the Future of the Furniture Industry.

From AC Spark Plug Division: **George A. Brown**, field contact engineer, before preventive maintenance supervisors of Ryder Systems, Incorporated, Tampa, Florida, title: Field Problems in the Installation and Servicing of Spark Plugs, before the Parts and Service Maintenance Association, Brookville, Florida, title: Proper Maintenance of AC Products in Automotive and Commercial Vehicles, and before fleet maintenance supervisors, Purdue University, title: Proper Maintenance of Spark Plugs in Fleet Operations; **Walter J. Banacki, Jr.**, project engineer, before the S.A.E. Filter Test Methods Subcommittee of the S.A.E. Engine Committee, Detroit, titles: Filter Pore Size Test Method and Flow Restriction Test; and **James H. DeVoe**, field engineer, before AC warehouse distributors, jobbers, and dealers, Seattle, Washington, title: Oil Filtration.

From GM Research Laboratories Fuels and Lubricants Department: **Paul A. Bennett**, supervisor, before the S.A.E., metropolitan section meeting, New York City, title: An Automotive Engineer Looks at Passenger Car Engine Lubrication Problems; and **Paul A. Bennett**, **M. W. Jackson**, research engineer, **Chester K. Murphy**, research engineer, and **Richard A. Randall**, senior research engineer, before the Philadelphia section, S.A.E., title: Reduction of Air Pollution by Control of Emission Crankcases.

Before the S.A.E. Greenbrier meeting, White Sulphur Springs, West Virginia: **Richard O. Painter**, head, Engineering Photography Department, GM Proving Grounds, title: Taming Motion with High Speed Photography.

Before the S.A.E. national west coast meeting, San Francisco: **Thomas B. Dilworth**, chief engineer, Electro-Motive Division, title: The Electrical Transmission for Railroad Locomotives, and **Howard W. Christenson**, head, research department, Allison Division, title: High Speed Tractor Steering Transmissions.

Bearings

From Hyatt Bearings Division: **John F. Moult**, assistant chief engineer, before the U. S. Naval Reserve Material Unit, Detroit, title: Engineering and Manufacture of Roller Bearings, and **Philip H. Hutchinson**, zone manager, before the Association of Iron and Steel Engineers, Cleveland, title: Why Straight Cylindrical Bearings in the Steel Industry?

From New Departure Division: **P. F. Reed**, supervisor, bearing service, before the American Society of Lubrication Engineers, Hudson-Mohawk section, Schenectady, New York, title: Bearing Failures—Their Types and Causes, and **Robert B. Walker**, project engineer, before engineers of Lamb Electric, North Canton, Ohio; Lincoln Electric Company, Cleveland; Grimes, Incorporated, Urbana, Ohio; and Robbins and Myers Company, Springfield, Ohio, title: Effect of Ball Bearings on Electric Motor Noise.

Computers

Dale F. Larson, senior project engineer, GM Manufacturing Staff, before the GM High School Science Teachers Conference, Detroit, title: Digital Computer Applications in Industry.

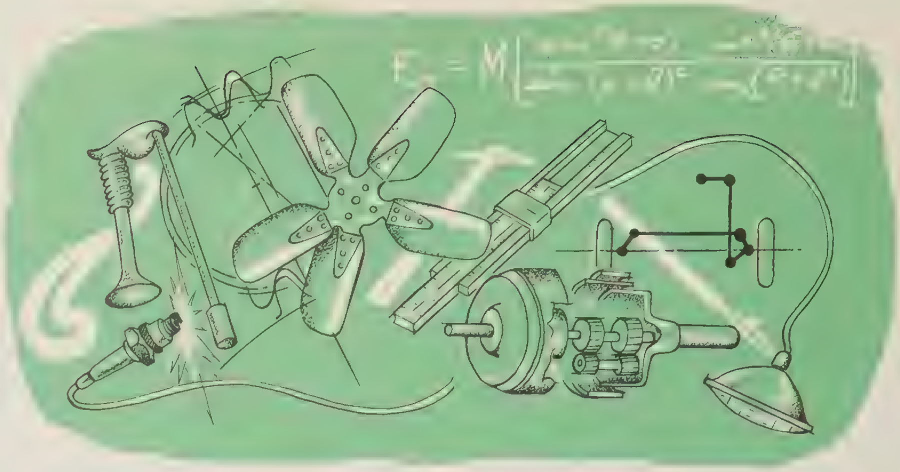
Ivan K. Lukey, product engineer, Buick Motor Division, before the S.A.E.,

Chicago, title: Computer Simulation of Automotive Fuel Economy and Acceleration.

From GM Research Laboratories: **Joseph B. Bidwell,** head, Engineering Mechanics Department, before the Gordon Research Conference on Instrumentation, New London, New Hampshire, title: Application of Computers to Automobile Ride and Steering Problems; **Gerald L. Licht,** senior research physicist, before the Operations Research Society of America, New York City, title: A Simulation of a Small Computer System on a Large Computer; **George F. Ryckman,** supervisor, Special Problems Department, before the A.S.M.E. design engineering show, New York City, title: Integration of a Computing Facility in an Engineering Organization; **Donald E. Hart,** assistant head, Special Problems Department, before the International Business Machines Seminar (Computers in Engineering and Engineering Education), Poughkeepsie, New York, title: Applications in Mechanical Engineering; and **Donald E. Hart** and **Barrett Hargreaves,** senior research engineer, before the National Electronics Conference, Chicago, title: DYANA—A Computer Program for the Automatic Analysis of Dynamic Systems.

Electrical Engineering

From Delco Radio Division: **J. R. Atkinson,** senior engineer, before the Greentown, Indiana, Lions Club, title: Transistors—What They Are and What They Can Do For Us; **R. D. Stroup,** field service engineer, before engineers and technicians of Redstone Arsenal, Huntsville, Alabama, title: Transistors; **Phil Powell,** field service engineer, before students of LaHabra, California, High School, title: Transistor Fundamentals; **William C. Caldwell,** service engineering coordinator, before instructors and administrators, Naval Electronics Training School, Great Lakes, Illinois, title: Transistors—Theory and Application; **Carl L. Meyer,** supervisor, Advanced Development and Materials—Semiconductors, before the midwest group of the American Institute of Chemists, title: Thermoelectricity; **J. R. Schaffner,** manager, Applications and Evaluations, before the 1960 Western Electronic Show and Convention, title: Quality Assurance Procedures for Power Transistors; and



Jack O. Beasley, field service engineer, before the National Alliance of Television Electronics Service Association, Wichita, Kansas, title: Transistors—Theory and Servicing.

Guided Missiles and Space Technology

From AC Spark Plug Division's Milwaukee, Wisconsin, plant: **Arthur R. Colgan,** technical coordinator, before the Wauwatosa, Wisconsin, Lions Club, title: Fundamentals of Missile Guidance, and before the Lakeshore Kiwanis Club of Sheboygan, Wisconsin, title: Basic Inertial Guidance and Missile Application; **William Gahan,** field service manager, before the Foreman's Safety School, Milwaukee, title: Safety With Missiles; **Robert James,** senior project engineer, before employes of the Wisconsin Electric Power Company, Milwaukee, title: The THOR IRBM; **Milton Knuijt,** senior project engineer, before the American Institute of Electrical Engineers, Milwaukee, title: Precision Units and Testing; **Joseph F. Shea,** director, Advanced Concepts—Research and Development, before the Controllers Institute of America, Milwaukee, title: Space—Problems and Potentials; **Harry C. Zeisloft,** administrative assistant, Engine Controls, before the Wisconsin Society of Professional Engineers, title: Inertial Guidance at AC; **Edwin F. Katz,** manager, Reliability—Inertial Components, before the American Welding Society, Milwaukee, title: Inertial Guidance; **Victor O. Muth,** senior project engineer, before the 7th grade class of Bayside School, Milwaukee, title: Missiles and AC Spark Plug; **Raymond A. Berg,** engineering program manager, before the Waukesha, Wisconsin, Rotary Club, title: Inertial Guidance at AC Spark Plug; and **Thomas C. O'Connell,** technical director, TITAN, before the Lakeside Bridge Management Club, Milwaukee, title: Missiles and Satellites.

Before the Fifth Symposium on Ballistic Missile and Space Technology, Los Angeles: **D. R. Whitney,** supervisor, Special Problems Department, GM Research Laboratories, title: Gyro Spin-Axis Bearing Program at the GM Research Laboratories; and **Ward D. Halverson,** research engineer, Allison Division, title: Electrograsdynamic Analysis of Ion Rocket Charge Neutralization.

Clayton L. Smith and **Milton D. Parker,** senior project engineers, Allison Division, before the American Rocket Society Space Power Symposium, Santa Monica, California, title: Stirling Engine Development for Space Power.

G. B. Hardenbrook, section manager, AC Spark Plug Division, Flint, before the Flint Evening Kiwanis Club, title: Automatic Guidance and Navigation Systems.

Highway and Traffic Engineering

Kenneth A. Stonex, assistant director, GM Proving Grounds, before the Ohio Turnpike Commission, Cleveland, and the Association of State and Provincial Traffic Safety Directors, Mackinac Island, Michigan, title: Roadside Design for Safety; before the S.A.E. Greenbrier meeting, White Sulphur Springs, West Virginia, title: Scientific Highway Design for Safer Motoring; and before the 14th annual Virginia Highway Conference, Lexington, title: Vehicle Aspects of the Highway Safety Problem.

Robert Herman, head, Theoretical Physics, GM Research Laboratories, before the Institute of Traffic Engineers, Chicago, title: The Theory of Traffic Flow.

Paul C. Skeels, head, Experimental Engineering Department, GM Proving Ground, before the Wisconsin State Highway design engineers, Madison, title: Roadside Design for Safety.

Harold M. Morrison, research engineer, GM Research Laboratories, before the conference of Western Association of State Highway Officials, Portland, Oregon, title: Automatic Highway and Driver Aid Development.

Instrumentation

John L. Harned, senior research engineer, GM Research Laboratories, before a joint meeting of the University of Detroit's A.I.E.E. and I.R.E. student chapters, title: Recording Instruments Aid Research Involving Measurement of Dynamics Phenomena, and before the Gordon Research Conference on Instrumentation, New London, New Hampshire, title: Dynamic Power Control Through Friction Contacts.

GM Research Laboratories personnel who appeared before the Joint Automatic Control Conference, Massachusetts Institute of Technology, Cambridge, included **Roy S. Cataldo,** senior research engineer, title: Analysis of Electrohydraulic Valves and Systems, and **John L. Harned,** senior research engineer, **P. Sudhindranath,** research engineer, and **K. M. Miller,** junior research engineer, title: Transfer Function Derivation for a New Departure Transitorq Variable Speed Drive.

Before the Instrument Society of America's Fall Instrument-Automation Conference, New York City: **Robert F. Spain,** designer, GM Research Laboratories, **Roger Wellington,** assistant staff engineer, Detroit Diesel Engine Division, and **Howard W. McKenna,** senior project engineer, Delco Radio Division, title: Vehicle Punched-Tape Data Acquisition System.

Manufacturing

Robert B. Colten, staff engineer, GM Manufacturing Staff, before the S.A.E. Production Forum Meeting, Milwaukee, title: Operating Experience with Numerically Controlled Machines.

John F. Cantalin, engineer in charge, Production Engineering Activity, Fisher Body Division, before the American Welding Society, western Michigan section, Grand Rapids, title: Resistance Welding Applications in Automotive Body Production.

David H. Hill, senior engineer, GM Manufacturing Staff, before the GM High School Science Teachers Conference, title: The Growth of a Program.

Metallurgy

From Allison Division: **Dean K. Hanink,** chief metallurgist, before Western Electric Company, Indianapolis, title: Some Problems Encountered and Solutions Developed on Materials Application to Turbojet and Turboprop Power Plants; and **George R. Sippel,** assistant plant metallurgist, before the 7th Sagamore Ordnance Materials Research Conference, Raquette Lake, New York, title: Instrumented Bend Tests Applied to Pressure Vessel Reliability, and before the Indianapolis chapter, American Society for Metals, title: Reliable High Strength Steel Rocket Motor Case Development.

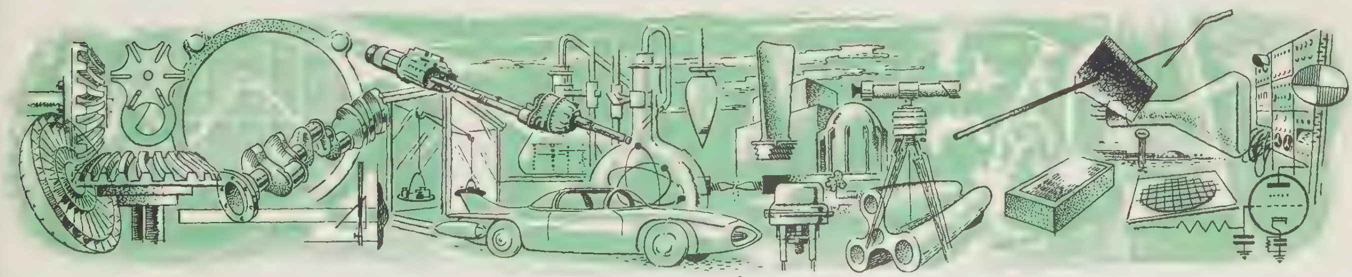
Claude H. Leland, senior metallurgical engineer, GM Manufacturing Staff, before the GM High School Science Teachers Conference, Detroit, title: Relation of Metallurgy to Industry.

William E. Lovell, engineer in charge, Process Engineering, Ternstedt Division, before the Saginaw Valley chapter, American Electroplaters' Society, Frankenmuth, Michigan, title: Experience in the Operation and Performance of Dual Chromium Systems.

From the GM Research Laboratories: **Robert F. Thomson,** head, Metallurgical Engineering Department, before the Philadelphia chapter of the American Society for Metals and before the western section of the Malleable Founders Society, Detroit, title: Metals and Materials for Automobiles of the Future: **William L. Grube,** assistant head, Physics Department, before the Chattanooga, Tennessee, chapter, A.S.M., title: Electron Metallography; and **T. J. Hughel,** supervisor, Metallurgical Engineering Department, and **D. J. Harvey,** senior research metallurgist, before the Detroit section, American Institute of Mining and Metallurgical Engineers, titles: Precision Mechanical Properties of Beryllium for Gyro Applications and Surface Tension, respectively.

Quality Control and Reliability

Robert V. Cole, superintendent, Receiving Inspection Quality Control—Vendor Contact, Allison Division, before the American Society for Quality Control



workshop-seminar, St. Louis, title: Quality Planning and Control of Incoming Parts.

Before the Detroit section, S.A.E.: **John R. Gretzinger**, director, Reliability and Quality, Buick Motor Division, title: Chassis and Total Car Reliability; **August J. Hofweber**, director, Product Reliability, Ternstedt Division, title: Body Component Reliability; and **William E. Sehn**, director, Product Reliability Activity, Fisher Body Division, title: Initiating the Body Reliability Program.

Research

R. W. Lee, research physicist, **D. E. Swets**, research physicist, and **R. C. Frank**, senior research physicist, GM Research Laboratories, before the A.S.T.M. Committee E-14 Meeting on Mass Spectrometry, Atlantic City, New Jersey, title: Anomalous Effects in the Diffusion of Gases in Fused Quartz.

S. R. Rouze, senior research physicist, and **W. L. Grube**, assistant head, Physics Department, GM Research Laboratories, before the 1960 Microscopy Symposium, Chicago, title: Thermionic Emission Electron Microscopy and its Use in the Study of High Temperature Transformation in Metals.

L. C. Rowe, senior research chemist, GM Research Laboratories, before the National Association of Corrosion Engineers, Pittsburgh, title: Combating Automobile Corrosion Problems Through Design, Special Processing, and Materials.

T. W. Selby, senior research chemist, and **N. A. Hunstad**, assistant head, Fuels and Lubricants Department, GM Research Laboratories, before the A.S.T.M. Symposium on Non-Newtonian Viscometry, Washington, D. C., title: The Forced Ball Viscometer and its Application to the Rheological Characterization of Mineral Oil Systems.

Robert Herman, head, Theoretical Physics, GM Research Laboratories, and R. Hofstadter, Stanford University, before the 10th International Conference on High Energy Nuclear Physics, Rochester, New York, title: Some Speculative Remarks on the Dirac and Pauli Form Factors of the Neutron.

R. J. Donohue, nuclear physicist, GM Research Laboratories, and H. Griem, consultant, University of Maryland, before the 13th Annual Gaseous Electronics Conference, Monterey, California, title: Spectroscopic Measurements of Plasma Temperatures and Densities in a High Pressure Cesium Diode.

W. D. Cheek, senior research physicist, GM Research Laboratories, before the American Society for Quality Control, Warren, Ohio, title: Fission, Fusion, and Confusion.

Personnel of GM Research Laboratories who made recent presentations at various scientific meetings include the following. Before the Michigan affiliate of the American Crystallographic Association: **Carl E. Bleil**, senior research physicist, title: Electron Bombardment of Solids, and **H. D. Nine**, research physicist, title: Photosensitive-Ultrasonic Properties of Cadmium Sulfide. Before the American Electroplaters Society, Boston branch: **J. D. Thomas**, senior research engineer, title: A.E.S. Research—Its Purpose and Accomplishments, and **C. F. Nixon**, head, Electrochemistry Department, title: A.E.S. Research Project on Accelerated Corrosion Testing. Before the Electron Microscope Society of America, Milwaukee: **H. M. Bendler**, research associate, title: Dynamic and Kinematic Theories of Electron Diffraction; **R. L. Scott**, research chemist, title: A Method of Mounting Specimens for Ion Bombardment Etching; **S. R. Rouze**, senior research physicist, and **W. L. Grube**, assistant head, Physics Department, title: Use of Thermionic Emission Microscopy and Cinematic Recording for Rate Studies of High-Temperature Transformation in Metals; **J. V. Laukonis**, senior research physicist, and R. V. Coleman, University of Illinois, title: The Study of Oxidation, Oxidation-Reduction, and the Thermal Etching of Iron Whisker Surfaces by Electron Microscopy; and **H. M. Bendler**, research associate, and W. A. Wood, University of Melbourne, Australia, title: Investigation of Fatigue in Copper by Electron Microscopy. Before the American Nuclear Society, Chicago: **A. H. Foderaro**, senior research scientist, and **H. L. Garabedian**, assistant head, Mathematics Group, titles: A New Method for the Solution of Group Diffusion Equations and the FORTRIX I Code; **H. A. Burley**, research engineer, and **Milton J. Diamond**, Central Foundry Division, title: A Fast Neutron System for Controlling the Moisture Content of Foundry Sand; and **F. L. Green** and **W. D. Cheek**, senior research physicists, titles: The Relative Flux Distribution of Neutrons in a Paraffin Moderator Using a Polonium-Beryllium Source and Experimental Photon Spectra of Sm^{153} Sources as a Function of Source Design. Before the Electrochemical Society, Houston, Texas: **S. E. Beacom** and **B. J. Riley**, senior research chemists, title: Mechanism of Addition Agent Reaction in Bright Nickel Deposition; **S. M. Selis**, senior research physical chemist, and C. R. Russell, consultant, title: An Analytical Representation of the Characteristics of Commercial Secondary Batteries; and **J. L. Griffin**, senior research physical chemist, and L. O. Case, University of Michigan, title: Effect of Electrode Vibration on Overpotentials of Lead in Sodium Plumbite and Alkaline Lead. Before the Symposium on Rolling Contact Phenomena, held at the GM Research Laboratories, Warren, Michigan: **R. C. Drutowski**, supervisor, Mechanical Development Department, title: The Linear Dependence of Rolling Friction on Stressed Volume; **L. D. Dyer**, senior research physical chemist, title: Rolling Friction on Single Crystals of Copper in the Plastic Range; **Fred G. Rounds**, senior research engineer, title: Effects of Lubricants and Surface Coating on Life as Measured on the Four-Ball Fatigue Test Machine; **J. J. Bush**, senior research engineer, **W. L. Grube**, assistant head, Physics Department, and **G. H. Robinson**, supervisor, Metallurgical Engineering Department, title: Microstructural and Residual Stress Changes in Hardened Steel Due to Rolling Contact; **L. O. Hewko**, design engineer, **F. G. Rounds**, senior research engineer, and **R. L. Scott**, research chemist, title: Tractive Capacity and Efficiency of Rolling Con-

tacts; and **R. K. Kepple**, senior research engineer, **R. L. Scott**, research chemist, and **M. H. Miller**, research physicist, title: The Effect of Processing-Induced Near Surface Residual Stresses on Ball Bearing Fatigue. Before the Operations Research Society of America Detroit: **F. B. Quackenboss**, research associate, title: Purchase and Storage Alternatives in a Spare Parts Supply System; **A. V. Butterworth**, research associate, title: Interfile Identification; and **Charles H. Fitts**, Allison Division, title: Optimization of Weapon Systems with Completely Monotone Cost and Capability. Before the Electrochemical Society, Wayne State University, Detroit: **R. L. Saur**, senior research physical chemist, title: Corrosion of Nickel in the CASS Test.

Technical Careers and Vocational Guidance

From Delco Radio Division: **J. E. Anderson**, process engineer, **Olburtus Ball**, senior tool engineer, and **E. R. Buehler**, technician, before students of Kokomo, Indiana, High School, titles: Mechanical Engineer, The Skilled Worker's Place in Industry, and Careers for Electronics Technicians, respectively.

From New Departure Division: **Bernard Kleban**, senior engineer, and **Leo Stella**, design engineer, before students of Eastern and Central High Schools, Bristol, Connecticut, titles: Engineering as a Career and Design Engineering, respectively.

From Guide Lamp Division: **Kenneth D. Musser**, process engineering supervisor, and **John A. Busby**, chief draftsman, before students of Anderson, Indiana, High School, titles: Mechanical Engineering—Its Place in Industry and Drafting in Industry, respectively.

R. L. Anderson, research chemist, GM Research Laboratories, before Redford Union High School science seminar, Redford Township, Michigan, title: Project From Start to Finish.

Miscellaneous

John M. Wetzler, project manager, small gas turbine engines, Allison Division, before the Waterloo, Iowa, Technical Society, title: The GMT-305 Engine.

Irvin E. Poston, senior engineer, GM Manufacturing Staff, before the GM High School Science Teachers Conference, Detroit, title: A New World of Plastics.

Philip S. Lang, director of work standards, Saginaw Steering Gear Division, before the American Society for the Advancement of Management, Detroit, title: Cost Reduction Through the Use of Predetermined Time Standards.

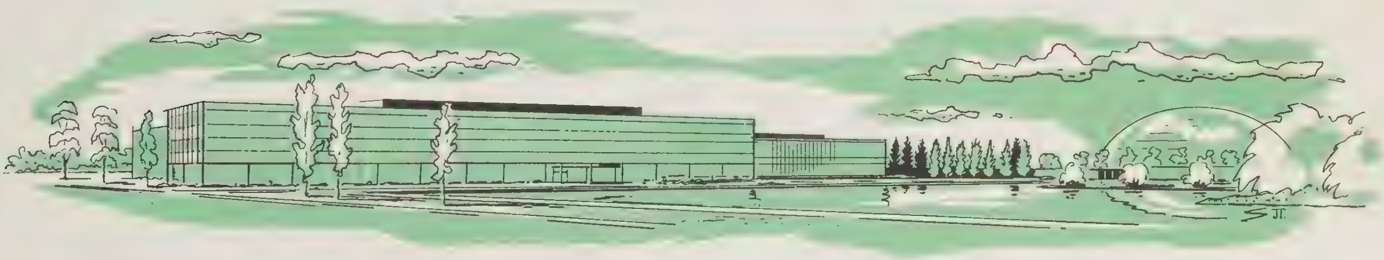
Alexander M. Beebee, plant engineer, Rochester Products Division, before the American Management Association seminar, Colgate University, title: Organization and Management of the Plant Engineering Function.

Harold S. Sharp, technical librarian, AC Spark Plug Division, Milwaukee plant, before the American Records Management Association, Milwaukee, title: Research—Why Repeat the Past?, and before the American Society for Metals, Milwaukee, title: Establishing a Company Information Center.

A. F. Underwood, manager, GM Research Laboratories, before the national Inventions and New Products Conference, Cleveland, title: Highway '60 to Invention.

From Delco Products Division: **Claude M. Willis**, safety director, before delegates of all Civitan Clubs in Ohio, Centerville, title: Traffic Safety, and **T. N. Schierloh**, technical service manager, before the southwestern chapter, National Industrial Service Association, Albuquerque, New Mexico, title: Silicon Rectifiers—Service Fundamentals.

From General Motors Institute: **Charles L. Tutt, Jr.**, administrative chairman, Fifth Year and Thesis Programs, before the 8th annual Engineering Management Conference, Chicago, title: Industrial Problem-Centered Student Development Program; **Adolph A. Klautsch**, senior specialist, psychology, before the Flint, Michigan, chapter, American Materials Handling Society, title: Escape Mechanisms for the Individual; and **D. C. Edmondson**, faculty member, Business and Accounting Department, before the American Accounting Convention, Columbus, Ohio, title: Business Games in Accounting Instruction.



Solution to the Previous Problem:

Design a Fixture to Grind Identical Replacement Tool Bits

By THEODORE W. JUDSON
General Motors
Institute

One example of applying descriptive geometry to a tooling problem is in the design of a fixture used in reproducing working surfaces of tool bits to match those of the original tool bit design. In developing the design of the fixture, the descriptive geometry principle of a plane intersecting a geometric shape is applied. This is the solution to the problem presented in the October-November-December 1960 issue of the GENERAL MOTORS ENGINEERING JOURNAL.

Descriptive geometry principle of a plane intersecting a geometric shape is applied

To perform its intended function, the surfaces of the fixture must be parallel to the working surfaces of the tool bit which is to be ground. A rectangular prism of reasonable size is first selected for layout around the product drawing of the cutting tool model (Fig. 1). To eliminate confusion when projections are made, the corners of the rectangular prism and the plane surfaces of the cutting tool model should be identified (Fig. 2).

The descriptive geometry principle of a plane intersecting a geometric shape is then applied. This principle involves drawing auxiliary views necessary to obtain an edge view of the plane. In such a view, it is possible to see all lines on the geometric shape cut by the plane.

The first auxiliary view drawn is a projection to find the true length of line *1-5* of the tool bit (Fig. 2, lower left). A second auxiliary view is then drawn to obtain line *1-5* as a point view (Fig. 2, upper left). This view also produces the edge view of planes *1-5-6-4* and planes *1-5-7-2*. The rectangular prism is projected into each auxiliary view.

In the second auxiliary view a plane is passed parallel to each plane of the cutting tool model to cut a plane surface from the rectangular prism. The planes of the cutting tool model and the planes intersecting the prism are parallel. This auxiliary view also shows at what point each edge line of the rectangular prism is cut by the plane. This point is termed a point of intersection of a line with a

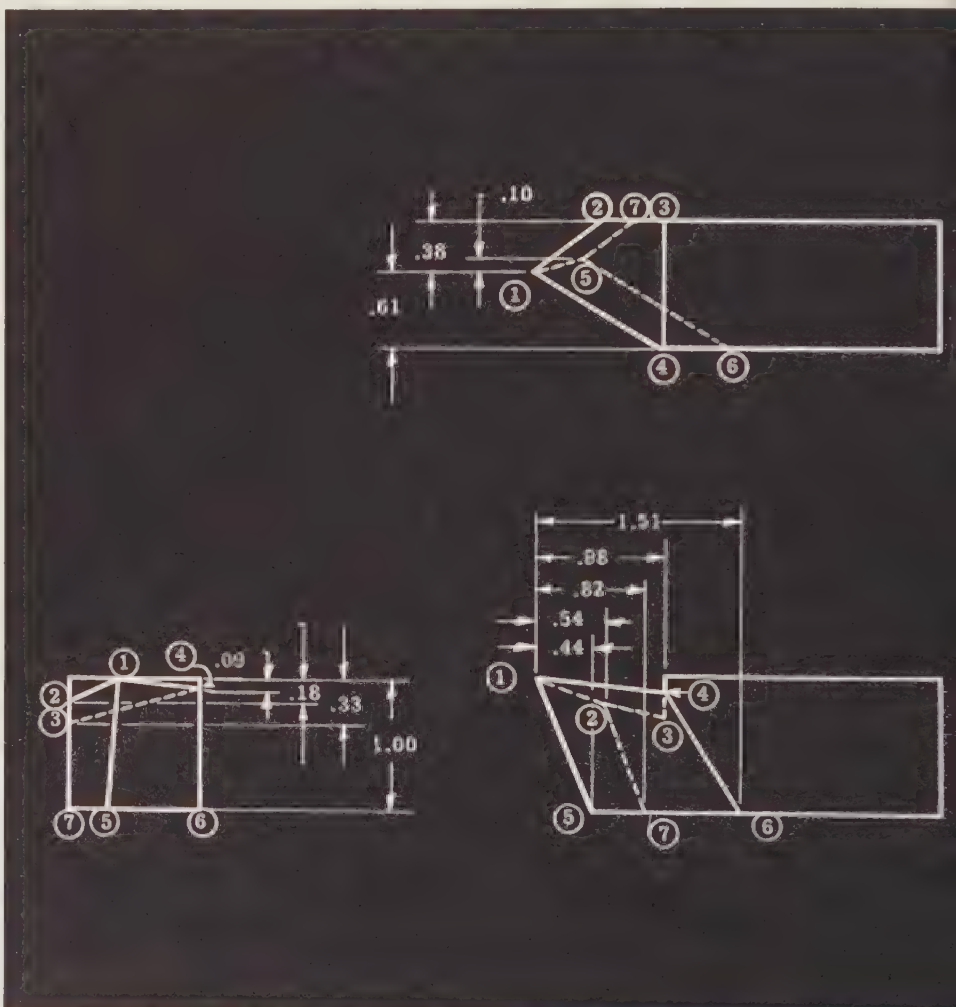


Fig. 1—This is a three-view product drawing of a single point cutting tool model. A fixture is to be designed for grinding a tool bit blank so that the cutting surfaces will match those of the model. The encircled numbers identify the plane surfaces of the tool bit.

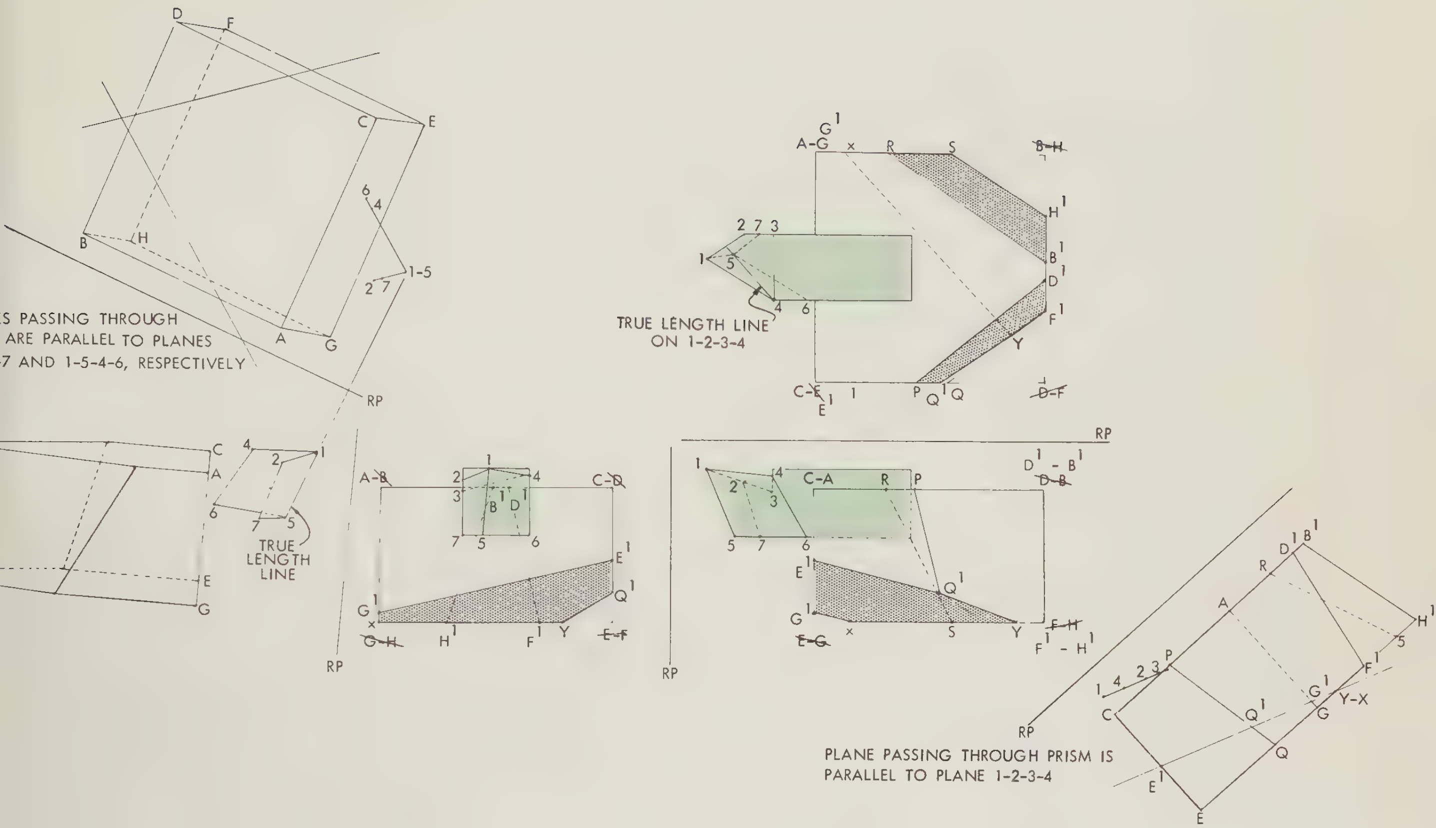


Fig. 2—The first step in developing the fixture is to draw a rectangular prism of reasonable size for layout around the cutting tool model, shown in color. The corners of the prism are identified as *A* through *H* and the plane surfaces of the cutting tool model as *1* through *7*. By applying the descriptive geometry principle of a plane intersecting a geometric shape, auxiliary views can be drawn to obtain an edge view of the plane and to see all lines on the geometric shape cut by the plane. Auxiliary views are drawn first to obtain line *1-5* in its true length and also as a point view. As a result, the planes *1-5-7-2* and *1-5-6-4* on the cutting tool model can now be drawn in an edge view. An additional auxiliary view is projected to construct plane *1-2-3-4* as an edge view. Points *P*, *Q*, *R*, *S*, *X*, and *Y* designate new points of intersection, not previously identified, which are produced by planes passed parallel to the plane surfaces of the cutting tool model and intersecting the prism. Points having a superscript, such as E^1 and Q^1, indicate the relocation of a point of intersection from its initial position on the prism. The design of the fixture is completed by adding necessary dimensions and design refinements.

plane. These points of intersection are then projected into the initial views of the fixture to show new surfaces on the rectangular prism.

At this point in the development of the fixture, the prism has a new shape. Thus, when projections are made to show the remaining plane *1-2-3-4* on the cutting tool model as an edge view, it is necessary to project this new shape into the auxiliary views. To obtain plane *1-2-3-4* as an edge view, a true length line is established on this plane. An auxiliary view is then drawn to show this true length line as a point view (Fig. 2, lower right). This view also produces the necessary edge view of plane *1-2-3-4*.

A plane passed parallel to plane *1-2-3-4* of the cutting tool model produces points of intersection where this plane cuts across the edge lines of the prism. These intersection points are projected to the initial views where the complete tool bit fixture is shown.

The design of the fixture may now be completed by adding the necessary dimensions on the initial views. At this stage, also, design refinements are added to the fixture to provide for proper lockup of the tool bit blank, ease of handling, and light weight.

To use the fixture, all that need be done is to mount the tool bit blank in the fixture and then position each plane surface of the fixture on the table of a surface grinder. The surface that is then ground on the tool bit blank will be parallel to its respective surface on the cutting tool model.

Educational Aids Currently Available to Educators

DESIGN ENGINEERING AND DRAFTING PROBLEMS

A kit containing four typical engineering design and drafting problems illustrating current automotive design and drafting practice is available to educators in the field of engineering design. Material for the kit was developed by four GM Divisions.

The current kit is similar to a kit previously made available and is not intended as a replacement. Three of the four problems in the previous kit remain the same, with the exception that all drawings for each problem have been up-dated to illustrate current automotive practice. A new design problem has been introduced.

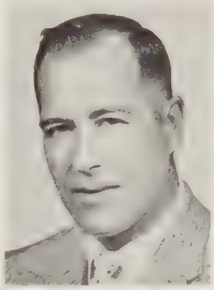
The four problems include: the design of a torque ball, the design of an instrument panel support, the development of a front door window regulator assembly, and the design of a crankshaft harmonic balancer assembly (this is the new problem). Preliminary explanations and drawings are included with each problem. All drawings in the kit are on blue line ozalids.

Educators interested in the design and drafting kit for classroom use may write to the Educational Relations Section, Public Relations Staff, General Motors Corporation, GM Technical Center, Warren, Michigan.

NEW MOTION PICTURE ON RELIABILITY

A new 16-mm motion picture entitled "A Matter of Responsibility" is now available for loan to educators at no charge, except that required for return postage. This film treats the subject of reliability, its applications in industrial plants, and the management responsibilities involved. The film was completed recently for showing to various GM groups and it is now being offered for loan to educators interested in this subject. Running time is 20 minutes. Copies may be obtained by writing to General Motors Corporation, Public Relations Staff, Film Library, General Motors Building, Detroit 2, Michigan.

Contributors to Jan.-Feb.-Mar. 1961 Issue of GENERAL MOTORS ENGINEERING JOURNAL

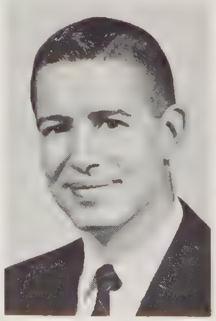


ARTHUR D. BLOCK, co-contributor of "A Nuclear Method for Measuring the Moisture Content of Foundry Sand," is a senior designer in the Physics Department, GM Research Laboratories.

His current work concerns designing, programming, and expediting various kinds of equipment used in the research projects of the Physics Department. Examples of this equipment are furnaces, powder dies, equipment for growing single-crystal and ferrite materials, and equipment for measuring sand moisture content. Previous design projects included contour follower machines and recorder units for checking gas turbine blades, and a 40-cfm volumetric air flow cylinder and console.

Mr. Block joined the Research Laboratories in 1948 as a senior tool designer in the Processing Department and was transferred to the Physics Department in 1955.

Before joining GM, Mr. Block had eight years of experience with several firms in the tool design field, where he completed an apprenticeship in shop and tool design work.



HARVEY A. BURLEY, co-contributor of "A Nuclear Method for Measuring the Moisture Content of Foundry Sand," is a senior research engineer in the Physics Department of the GM Research Laboratories.

Mr. Burley joined the Research Laboratories in 1955 as a research engineer in the Physics Department. In 1959 he was transferred to his present assignment in the Department's Isotope Laboratory. Mr. Burley's current work as a senior research engineer, a position he assumed in 1960, concerns investigating the feasibility of applying radioisotope techniques to industrial processes. When such techniques are feasible, as in the case of the nuclear moisture gage described in this issue, he then is concerned with the design, installation, and testing of such equipment. Prior to his current responsibilities, he was concerned with the application of electronic and sonic techniques to the field of nondestructive testing.

Mr. Burley received a B.S.E.E. degree from the University of Michigan in 1950. He is a member of the Institute of Radio Engineers' Professional Group on Nuclear Science, the American Nuclear Society, and is a charter member of the Michigan Nucleonics Society. Prior to joining GM, he was associated with Radioactive Products Incorporated and the Detroit Edison Company.

MILTON J. DIAMOND, co-contributor of "A Nuclear Method for Measuring the Moisture Content of Foundry Sand," is a research engineer for Central Foundry Division. He is currently engaged in developmental work for future processes relating to foundry technology.

After receiving the bachelor of electrical engineering degree from the University of Detroit in 1932, Mr. Diamond worked as a student engineer for the Consumers Power Company of Michigan. He joined General Motors in 1934 as a technician in the sand laboratory of Saginaw Malleable Iron Division, which later was renamed Central Foundry Division. After promotions to electrician, draftsman, and electrical engineer, he was appointed to his present position in 1953.

Mr. Diamond's previous projects have included developmental work on specialized flame hardening equipment, automatic sprue-burning machines, nondestructive testing of castings by the sonic method, and electrical engineering

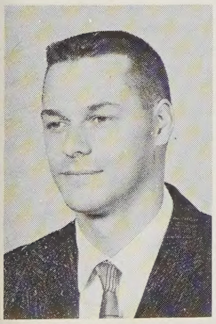
work in connection with new plant construction.

He is a member of the GM Committee on Non-Destructive Testing and the GM Electronics Sub-Committee. He has contributed several papers relating to magnetic and electronic methods of casting inspection to the Society of Automotive Engineers and to trade publications.

WARD F. DIEHL, co-contributor of "A Problem in Developing Special Purpose Machines: Reducing the Drive Power Requirements," is senior engineer in charge of fluid power and special test equipment, GM Manufacturing Staff, Manufacturing Development. His duties include supervising the development of a variety of test equipment and special machines which involve applications of hydraulic and pneumatic principles. Typical projects are testing of fire resistant fluids, developing test equipment for automatic transmission controls, and developing pneumatic systems to control automatic machines.

Mr. Diehl joined General Motors in 1937 as a General Motors Institute cooperative student, sponsored by Fisher Body Division. His early experience was in tool and special machine design which led to his appointment in 1947 to the Manufacturing Staff as project engineer, Process Development Section. In 1953 he was named fluid power engineer and was advanced to his present position in 1955.

General Motors Institute awarded Mr. Diehl the B.M.E. degree in 1949. He is a registered professional engineer (Michigan) and a member of the Engineering Society of Detroit. One patent has resulted from his work in developing gyrofinishing, a metal finishing process using automatic machinery.



ROBERT E. FARRAR, co-contributor of "A Problem in Developing Special Purpose Machines: Reducing the Drive Power Requirements," is a junior engineer, GM Manufacturing Staff, Manufacturing Development. His current duties are concerned with the application of hydraulic and pneumatic power to special machines and machine control systems. Previous projects on which he has worked include: a commutator molding machine, a cylinder head assembly machine, a rear-wheel toe-in machine for assembly of Chevrolet Corvair automobiles, germanium gaging, transistor assembly, and electrical discharge machining.

Mr. Farrar joined the Manufacturing Staff in 1955 as a technician. He was promoted to his present position in 1958. He received the B.S. in mechanical engineering degree from Lawrence Institute of Technology in 1958.

JAMES H. GUYTON, co-contributor of "The Organization of Research and Engineering Activities at Delco Radio Division," is chief engineer—radio at Delco Radio.

His experience in the radio and electronics fields covers a period of about 25 years, most of it with Delco Radio. He joined the Division in 1937 as a junior electrical engineer, and subsequently, held the positions of section head of advanced radio development, and assistant chief engineer—electrical, before appointment to his present position in 1957. His work has resulted in nine patents, a number of them applicable to military equipment. The general areas of responsibility in his present position are described in the paper which he co-authored for this issue.

Washington University, of St. Louis, granted Mr. Guyton the B.S.E.E. degree in 1934 and the M.S.E.E. degree in 1935. He was elected to Tau Beta Pi and Sigma Xi, honorary societies.

Other societies of which he is a member include the Institute of Radio Engineers, American Astronautical Society, and the Armed Forces Communications Society. He also serves on a number of technical committees in the radio and electronics fields. He has contributed other technical papers for publication including one in Vol. 1, No. 1 of the JOURNAL.

BARRETT HARGREAVES, contributor of "GMR DYANA: The Computing System and its Applications," is a senior research engineer in the Data Processing Group, Special Problems Department, GM Research Laboratories. His present responsibilities include the development of advanced digital computer applications.

Mr. Hargreaves joined the Research Laboratories in 1957 as a research engineer in the Special Problems Department. He was promoted to his present position in 1960. His previous major projects have included cam stress analysis, computer solution of differential equations, and development work on the GMR DYANA program.

Mr. Hargreaves received the B.S.E.E. degree from Michigan State University in 1952 and the M.S.E.E. degree from Wayne State University in 1960. He was elected to Tau Beta Pi, Eta Kappa Nu, and Pi Mu Epsilon, honorary societies. His technical affiliations include membership in the A.I.E.E. and the Association for Computing Machinery.

Before joining GM, Mr. Hargreaves was employed for three years by the Detroit Edison Company in analog computer work.

DR. FRANK E. JAUMOT, JR. co-contributor of "The Organization of Research and Engineering Activities at Delco Radio Division," is director, research and engineering—semiconductors, at Delco Radio. His responsibilities include the direction of all semiconductor research, development, and applications, and also transistor pilot production lines.

Dr. Jaumot received the B.S. in physics degree from Western Maryland College in 1947 and the Ph.D. in physics degree from the University of Pennsylvania in 1951. After graduation he remained at the University of Pennsylvania as an instructor in physics until joining the Franklin Institute in 1952 as chief, Physics of Metals Section. While working

for the Institute, he remained on the staff of the University of Pennsylvania on a part time basis as a visiting assistant professor of metallurgy.

Dr. Jaumot joined Delco Radio in 1956 as assistant chief engineer—semiconductors, and was promoted to his present position in 1957. He has contributed 22 papers to various publications and has co-authored two books.

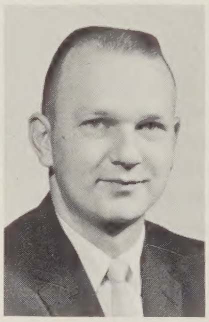
Some of the technical and professional societies of which he is a member include Sigma Xi; American Physical Society; American Crystallographic Society; American Institute of Mining, Metallurgical, and Petroleum Engineers; Institute of the Aeronautical Sciences; American Institute of Physics; Scientific Research Society of America; and the Institute of Radio Engineers.

THEODORE W. JUDSON, contributor of the problem "Design a Fixture to Grind Identical Replacement Tool Bits," and the solution appearing in this issue, is a faculty member of the Production Engineering Department at General Motors Institute. His teaching responsibilities are in two primary areas: (a) the physics of metal cutting as related to factors influencing machinability and (b) process planning and tool design principles in the solution of manufacturing problems.

Mr. Judson joined the faculty of G.M.I. in 1953 as an instructor in the Engineering Drawing Department. In 1960 he was transferred to the Metal Cutting Section of the Production Engineering Department. While with the Engineering Drawing Department he was given responsibility for the development and teaching of an engineering drawing program for the GM Engineering Staff.

Mr. Judson was granted a B.S. degree from Eastern Michigan University in 1951. He received an M.A. degree from the University of Michigan in 1958.

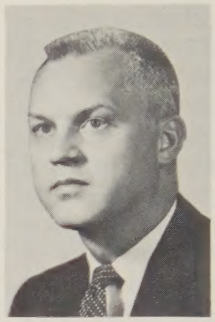
He is a member of the American Society of Tool and Manufacturing Engineers and also is faculty advisor to the Tool Engineers Club at G.M.I.



C. RICHARD LEWIS, contributor of "GMR DYANA: Extending the Computing System to Solve More Complex Problems," is a mathematical programmer in the Data Processing Group, Special Problems Department, GM Research Laboratories. He is presently concerned with the solution of dynamics problems by a digital computer, including consultation on DYANA programs and modifications of the DYANA system.

Mr. Lewis received the Bachelor of Science degree from Wayne State University in 1954. He is currently completing requirements for the Master of Science degree from the same university.

Prior to joining General Motors in 1959, Mr. Lewis was employed in the automotive industry developing basic computer programs, including the solution of dynamics problems by a digital computer.

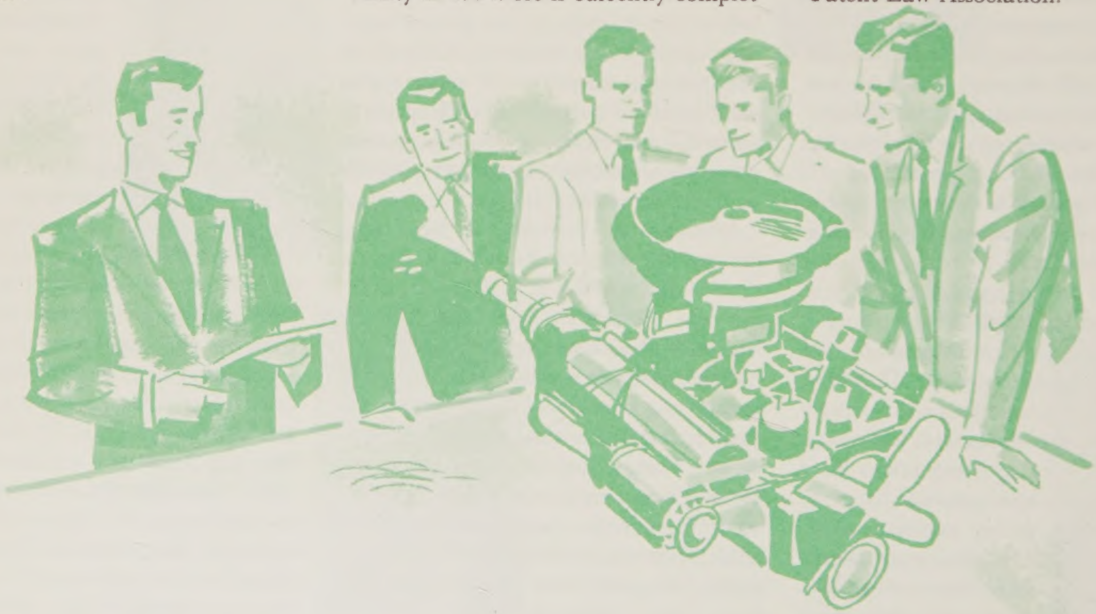


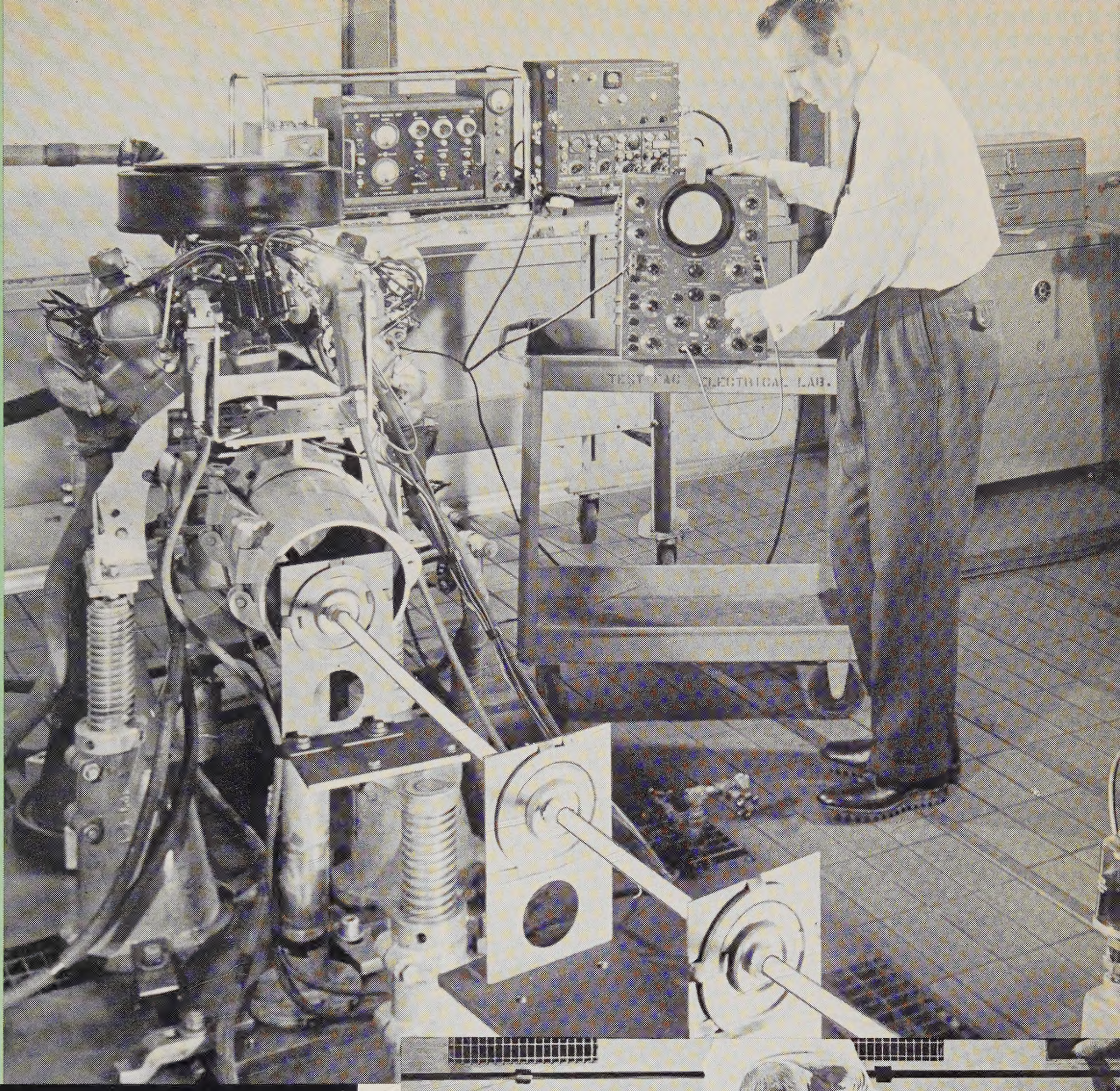
CREIGHTON R. MELAND, contributor of "United States Patents as Prior Art," and coordinator of this issue's "Notes About Inventions and Inventors," is a patent attorney in the General Motors Patent Section's Dayton, Ohio, Office.

Mr. Meland is a graduate of the University of Wisconsin, B.S.E.E., 1952, and George Washington University, LL.B., 1955. He joined General Motors in 1952 in the Washington, D. C., Office of the Patent Section as a patent engineer. Four years later, he transferred to his present position in the Dayton Office.

His duties are concerned with the preparation and prosecution of patent applications and patent infringement and validity investigations relating primarily to devices in the electrical, electronic, and electromechanical areas.

Mr. Meland is a registered patent attorney and a member of the Bar of District of Columbia. His society affiliations include the American Institute of Electrical Engineers and the American Patent Law Association.





ENGINEERING ASSIGNMENT IN GM

The flexible drive shaft of the Pontiac Tempest automobile requires no universal joints but still permits angular misalignment between output and input ends of the shaft. Its use results in virtual elimination of the floor tunnel in this passenger car.

A design concept of the Pontiac Motor Division, this shaft underwent exhaustive testing by the General Motors Engineering Staff during its development. One of the requirements met by Engineering Staff personnel was the development of highly specialized test instrumentation to assist in the determination of placement and damper arrangement for the shaft. Test apparatus also was developed to evaluate the effects of bend angle, torque, offset, and runout of the shaft on drive line vibratory amplitude and end moments.

Horizontal and vertical end moments of the drive line were measured with a specially designed force fixture which utilized strain gage load rings to indicate forces resulting from the shaft bend angle. Amplitude values were recorded as the type, number, and position of experimental vibration dampers were varied along the shaft. The operating temperatures of the bearings in the dampers also were recorded.

In the photograph, Duane Wright, supervisor of test operations, Test Facilities Instrumentation Section, Engineering Staff, is observing torsional vibrations of the flexible drive line system operating in an engine dynamometer test cell. Major components of the instrumentation are the oscilloscope, recording oscillograph, bridge balance box, carrier amplifier system, and torque measuring system. The inset shows the flexibility of the drive line.

Mr. Wright joined the Engineering Staff in 1957 as an instrumentation engineer. He was promoted to his present position the following year. He designs and specifies instrumentation systems for a wide range of engineering development projects, and coordinates the work of laboratory technicians with the requirements of project engineers. He is a 1955 graduate of General Motors Institute, earning the degree of Bachelor of Mechanical Engineering. While attending G.M.I. in the cooperative engineering program, he worked at the GMC Truck and Coach Division.

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